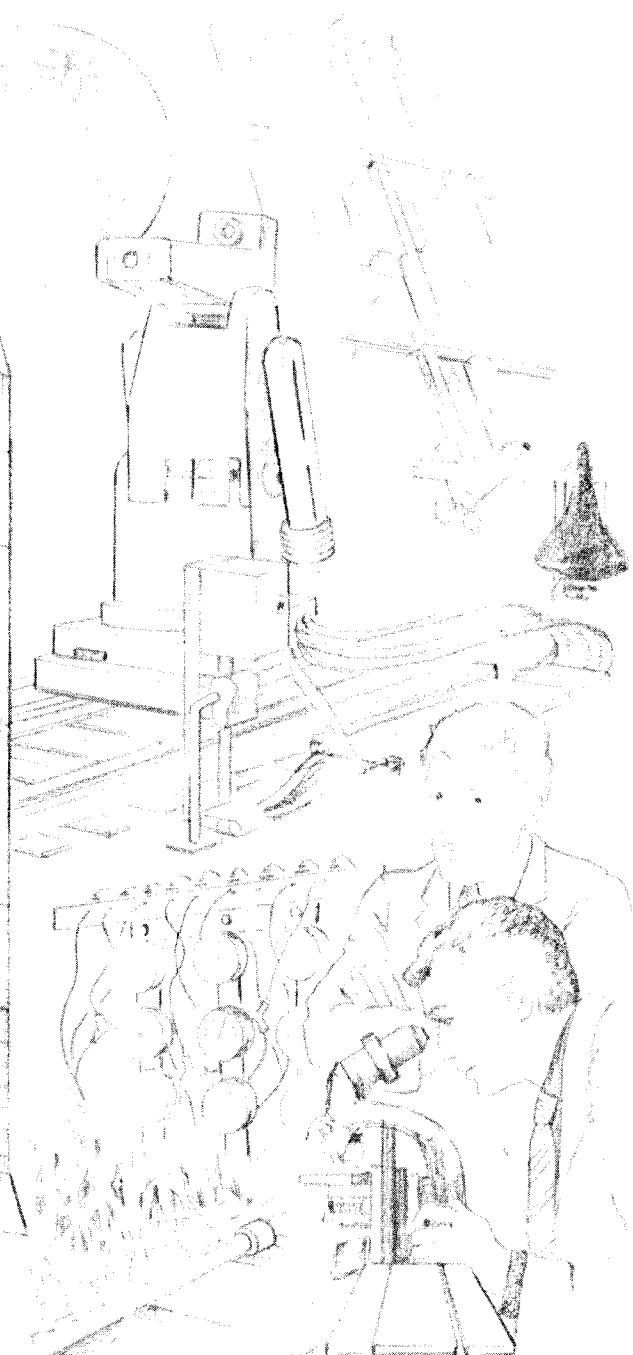
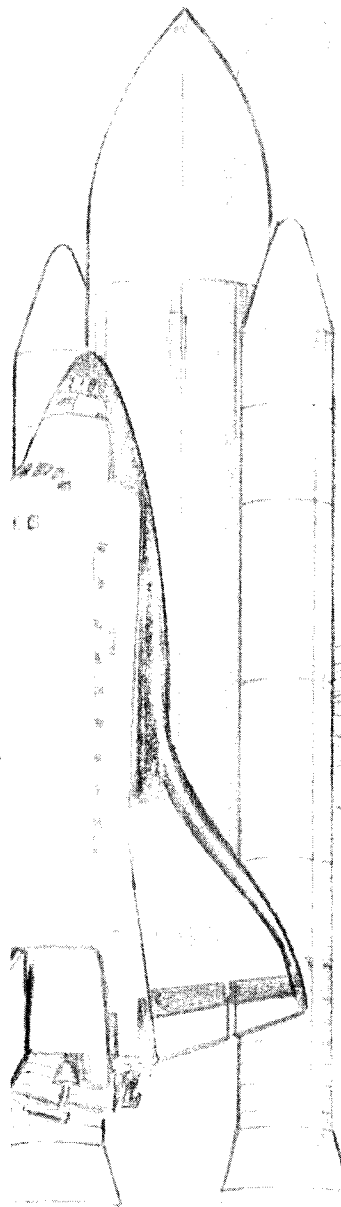
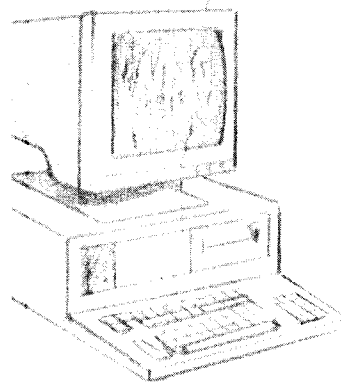


# RESERCH AND TECHNOLOGY

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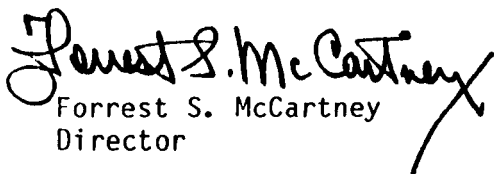
## John F. Kennedy Space Center

**Research and Technology  
1987 Annual Report  
of the John F. Kennedy  
Space Center**

## FOREWORD

As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to future programs. The Engineering Development Directorate encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation, and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1987 Annual Report.

For further technical information about the projects, contact David A. Springer, Projects Management Office, DE-PMO, (305) 867-3035. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.

  
Forrest S. McCartney  
Director

### **AVAILABILITY INFORMATION**

For additional information on any summary, contact the individual identified with the highlight. Commercial telephone users may dial the listed extension preceded by area code 305. Telephone users with access to the Federal Telecommunications System may dial the extension preceded by 823.



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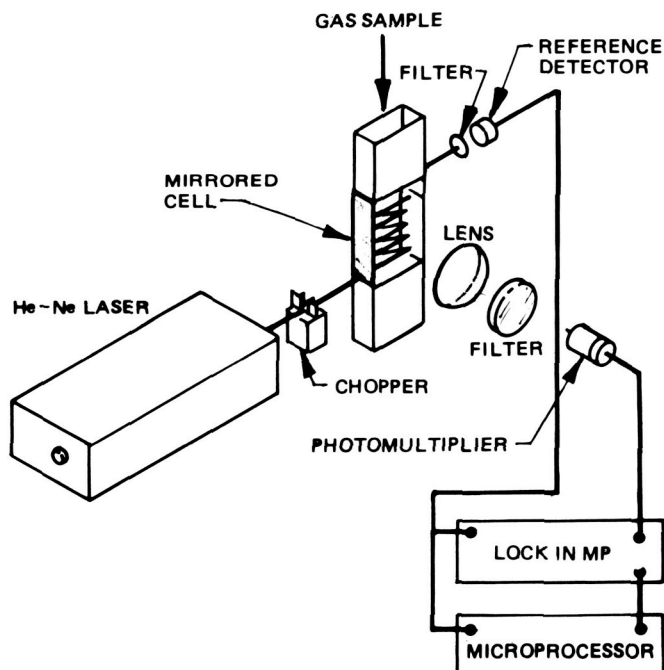
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# INSTRUMENTATION AND HAZARDOUS GAS

## Hydrogen Laser Monitoring System (HLMS)

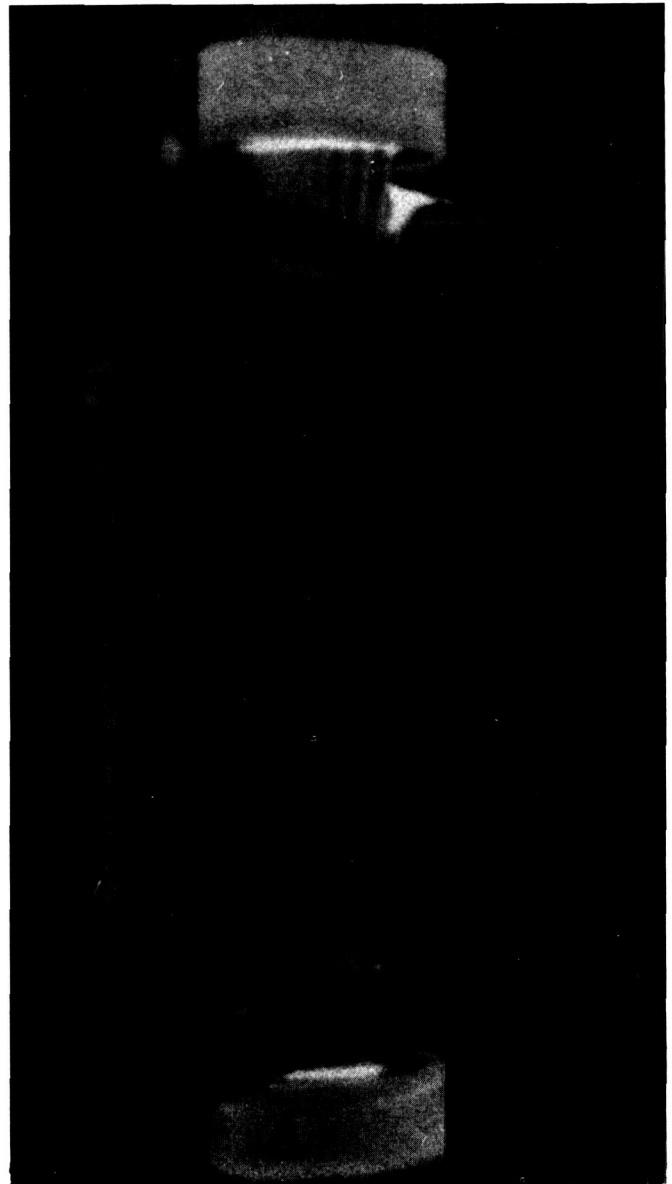
The checkout and launch of space vehicles involves measurement of a large number of parameters in a field operational environment. A reliable, low-maintenance hydrogen ( $H_2$ ) gas monitor is needed to check for leaks in gas purge lines and guard against flammability conditions in the launch of the Space Shuttle. This instrument would ideally be deployable in the Mobile Launch Platform directly under the Shuttle. It must have a sensitivity of tenths of a percent  $H_2$  up to ten percent or more, and must give accurate readings in a variety of sample gases, including nitrogen ( $N_2$ ), helium (He), air, or any mixture of the three.

The basic concept of HLMS is the measurement of  $H_2$  concentration by detection of its characteristic Raman scattering when illuminated by a laser. Monochromatic light from an argon ion or helium-neon laser enters a multipass optical cell where it traverses back



HLMS System Diagram

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Hydrogen Laser Monitor System Sample Chamber

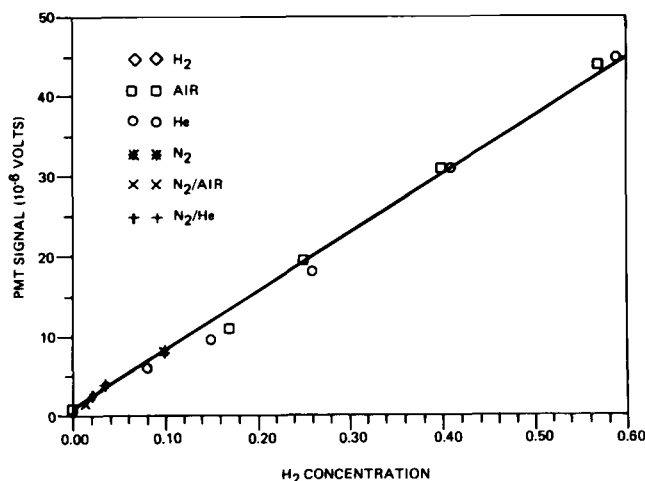
and forth through a sample region containing the gas to be analyzed. Raman-scattered light generated by the  $H_2$  in the sample is shifted in wavelength by a characteristic amount. This Raman light is collected and passed through a narrow band-pass filter which blocks the non-shifted laser light and other undesired

radiation, and it is detected by a photomultiplier tube. Since a chopper is used to modulate the laser light, the Raman signal is modulated as well, enabling the use of lock-in detection to reject ambient light and photomultiplier noise. The output of the lock-in circuitry, which is proportional to the  $H_2$  concentration in the sample, is converted to the desired instrument output signal (for example, a 1-5 volt analog channel).

The Raman technique has unique advantages over many alternative approaches. The Raman scattering is exactly proportional to the  $H_2$  number density in the sample region, and is independent of the nature of the background gas. These properties make calibration of the HLMS instrument simple and reliable.

The overall objective of the Phase I effort was to provide a proof of principle demonstration of the proposed  $H_2$  concentration sensor. This effort involved the construction and testing of a laboratory breadboard system consisting of a laser system, a Raman scattering cell for the sample, a detection system, and the associated electronics. The breadboard testing demonstrated the ability to measure  $H_2$  concentration in  $N_2$ , He and air, and to quantify the Raman signal in varying concentrations of these gases. These tests also established the sensitivity, data handling requirements, and other parameters necessary to carry the HLMS instrument to the prototype stage. A preliminary design for a Phase II prototype HLMS was also developed.

The concept of using Raman scattering for sensitive and accurate detection of hydrogen concentrations in gas samples has been successfully demonstrated in the laboratory. Two laboratory breadboard instruments, based on low power, air-cooled helium-neon and argon ion lasers, respectively, were designed, built and tested in the HLMS Phase I program. For both instruments, the performance was in good agreement with theoretical calculations of absolute signal and noise levels and sensitivity. The demonstrated  $H_2$  detectable limits in 1 atm of carrier gas with a 2-second time constant were 2,000 parts per million with the HeNe laser and 200 parts per million with the argon ion laser. The proportionality of the signal to  $H_2$  concentration and the absence of interference from air, nitrogen, and helium carrier gases were demonstrated to within the instruments' sensitivity. The independence of the  $H_2$  signal of the carrier gas composition was also demonstrated to within experimental error. The proportional relationship and carrier gas-independence of the signal are in full accord with the well-known properties of the Raman effect. A continuous 24-hour test of the argon ion laser apparatus



Signal vs  $H_2$  Concentration

found the signal to be stable within experimental error. The demonstrated sensitivity, linearity, and stability of the argon ion laboratory instrument strongly indicates that a successful prototype HLMS instrument can be developed in Phase II.

William R. Helms, 867-4438

DL-ESS-31

## Rocket Engine Leak Detector Mass Spectrometer (RELDMS)

The present primary and backup Hazardous Gas Detection Systems are ground-based and remotely located from Shuttle engines (SSME). Sample line lengths of approximately 200 feet result in sample transport delays of about 20 seconds. The small number of sample locations (1 line, 2 sample points) does not permit localization of leak sources. SSME leak monitoring is terminated at approximately T-38 seconds in the launch sequence. The goal of the design trade study performed during the past fiscal year was to specify a flight mass spectrometer which could provide instantaneous go/no-go information.

The design trade study has resulted in a preliminary specification for a 4-gas mass spectrometer for this project. The mass spectrometer will include a sampling system that will function from sea level to an altitude of approximately 17,000 feet. The estimated size (0.6 cubic feet), weight (36.5 pounds), and power consumption (80 watts) of the proposed instrumenta-



tion meets NASA requirements. The proposed measurement ranges for each gas are:

Hydrogen:	200	to	200,000	ppm
Helium:	100	to	100,000	ppm
Nitrogen:	150	to	1,000,000	ppm
Oxygen:	200	to	250,000	ppm

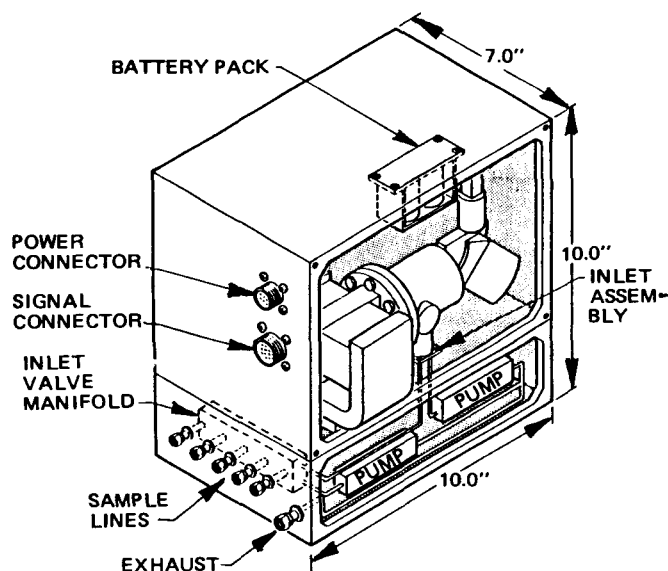
The single focusing magnetic sector mass spectrometer was selected as the best configuration for this application. A single permanent magnet will be employed for simplicity to achieve clear mass separation. A sintered metal inlet leak was selected for its proven stability and ruggedness. Multiple gain hybrid electrometers will be employed to meet the dynamic range requirement and to minimize microphonic concerns.

Sampling system concepts were extensively evaluated. Six sample points per analyzer will be used, each being a maximum of 10 feet from the analyzer. Sample transport time will be approximately 0.8 seconds and sample analysis rate will be 2 sample lines per second.

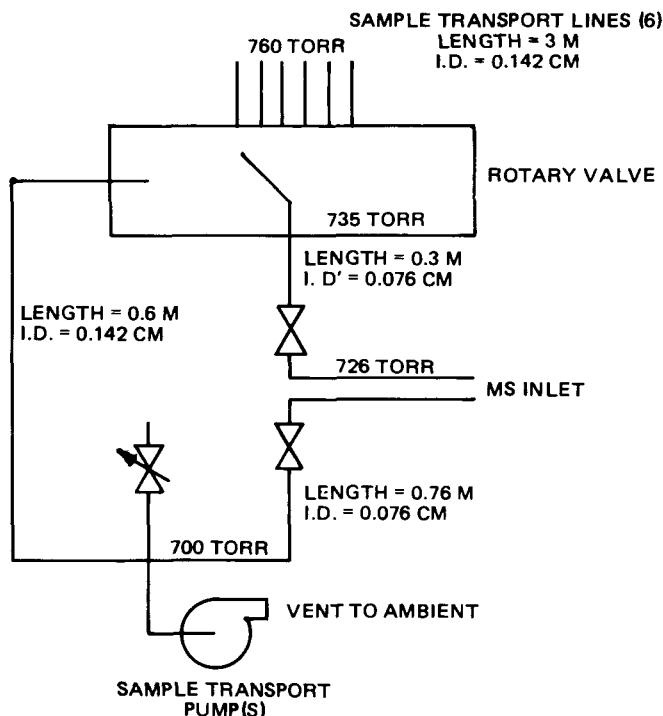
The next step in the RELDMS project is to develop a prototype. Three critical subassemblies (ion source, ion pump, and electrometer) will be subjected to realistic SSME vibration profiles. A rotary sampling valve will be developed. Finally, a developmental unit will be assembled for laboratory and field tests.

J. David Collins, 867-4438  
William R. Helms, 867-4438

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*Analyzer Module Conceptual Packaging*



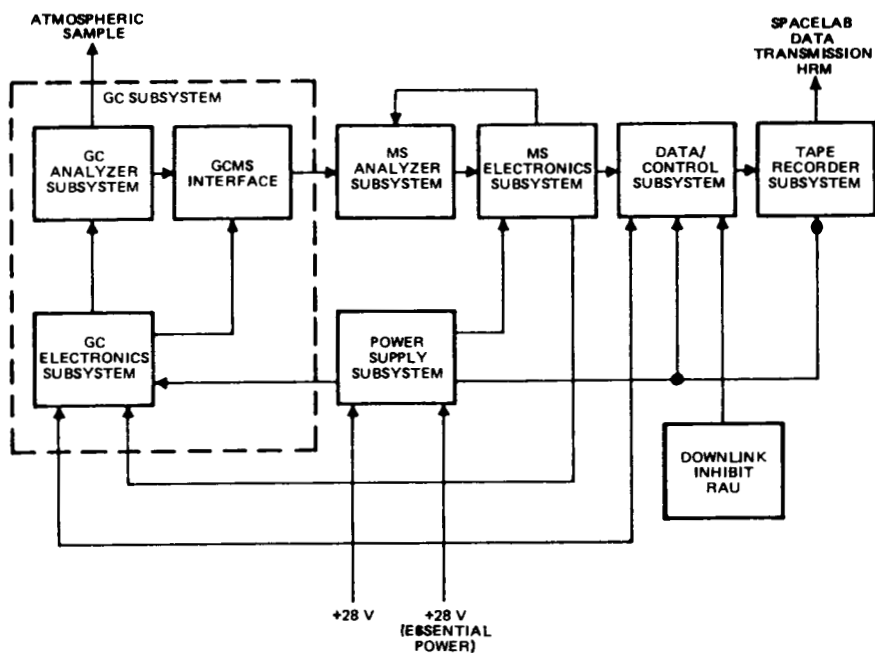
*Sample Transport/Transfer System*

## Trace Gas Analyzer (TGA)

The Trace Gas Analyzer (TGA) is a gas chromatograph/mass spectrometer (GCMS) that was designed to monitor contaminant levels in closed atmospheres. The current design evolved from a NASA requirement for a space qualified contaminant monitor for Space-lab. Under NASA's auspices, several improvements have recently been made to the TGA to adapt it for potential Space Station use. The TGA that was built as the Qualification Unit has been modified and is now being tested in the Marshall Space Flight Center Space Station Environmental Control and Life Support System (ECLSS) Simulator.

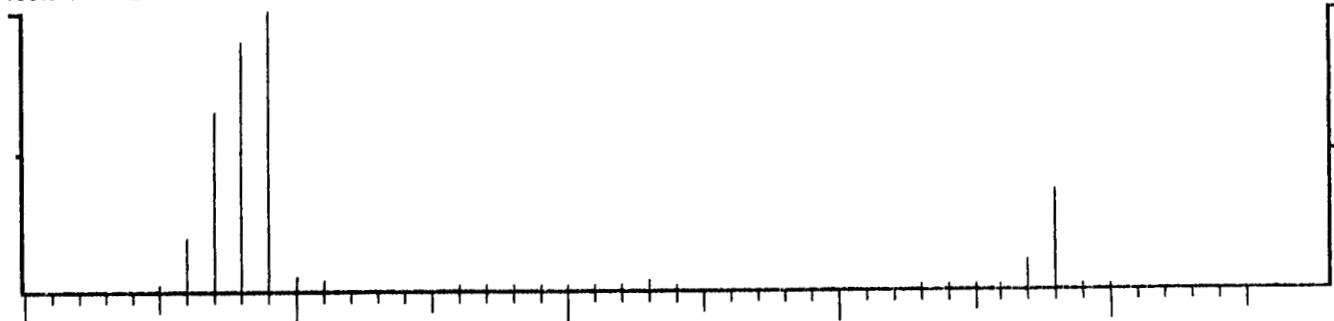
The TGA was initially designed and built to monitor the spacecraft cabin atmosphere for organic compounds and for carbon monoxide. The most recent program improved the TGA data subsystem and the gas chromatograph subsystem. The mass spectrometer subsystem was not altered.

The original TGA data subsystem provided data acquisition and storage on tape. These data were then to be transmitted to Earth for analysis. The data sub-system has been updated to include a self-con-

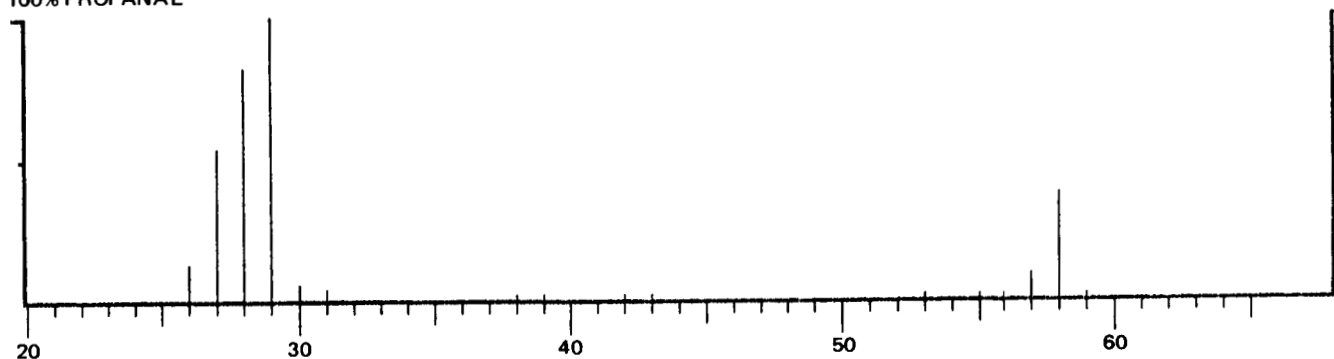


Block Diagram of TGA

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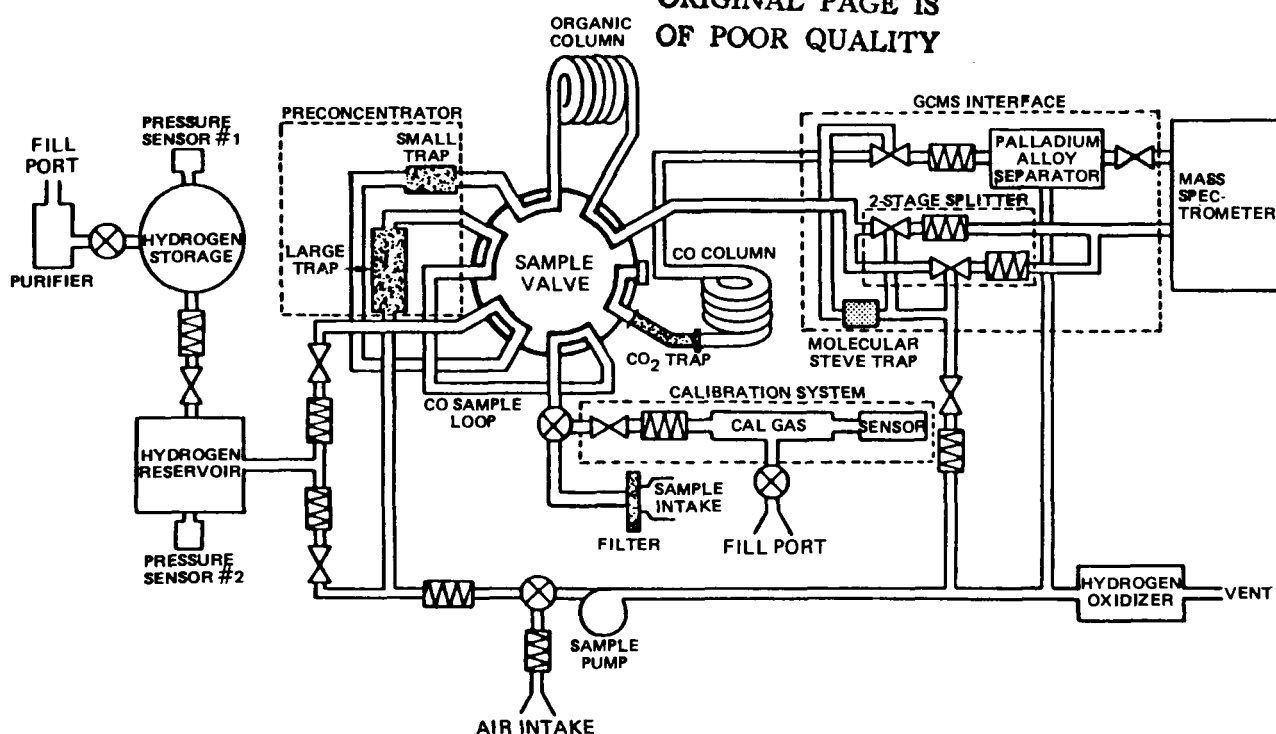
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Flow Schematic for TGA

tained capability for quantitative and qualitative data analysis using an IBM PC XT. A Finnigan MAT GCMS computer program is used to search a mass spectral library of 50,000 compounds to identify unknown species by pattern recognition techniques. The new data subsystem yielded generally satisfactory results. A test gas mixture of 9 compounds (see Table 1) was successfully analyzed except for carbon tetra-chlo-

ride. Further work is required to understand this compound's elusiveness during this demonstration.

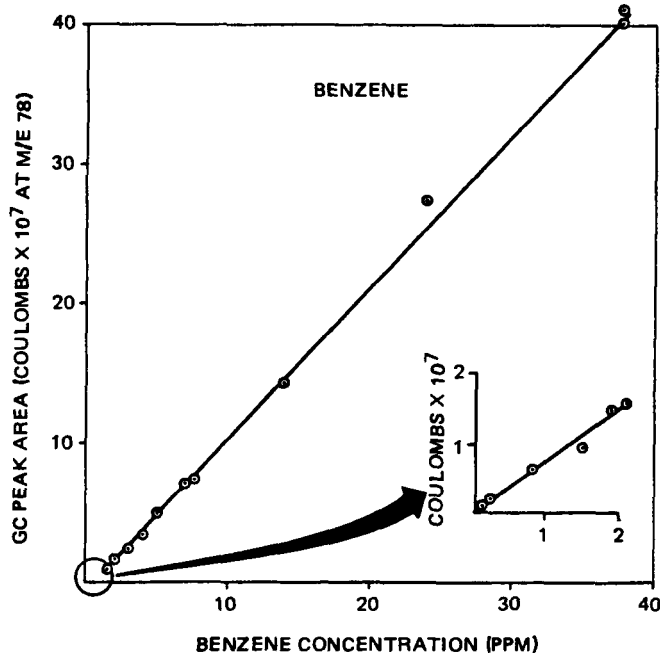
While providing excellent performance as an organic monitor, the TGA's function as a CO monitor was unsatisfactory. Sensitivity to CO was not adequate and the task of CO analysis compromised the overall performance of the instrument. The gas chro-

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SORTED VIA: ENTRY NUMBER      (S) = STANDARD

CAL	NAME OF COMPOUND	S	SCAN #	R TIME	ME	CALC AMT (A)	UNITS
1	O-DICHLOROBENZENE	E	699	49:14	BY	12.262	PPM
2	MESITYLENE	E	483	33:59	BB	11.625	PPM
3	DIOXANE	E	242	16:59	YB	13.531	PPM
4	METHYL ISOBUTYL KETONE	E	229	16:04	BY	23.003	PPM
5	FLUOROBENZENE	E	188	13:10	BB	5.419	PPM
6	BENZENE	E	164	11:29	YB	2.721	PPM
7	PROPANOL-2	E	153	10:42	BB	54.846	PPM
8	ETHYL ACETATE	E	132	9:14	BB	48.343	PPM
9	PROPENAL	E	100	6:58	BB	51.448	PPM

Quantitation Report





#### Test Results for Benzene

matograph subsystem was modified to by-pass hardware and software associated with carbon monoxide analysis. This change provided several advantages. The GCMS analysis cycle was reduced from 154 minutes to 120 minutes. This includes a warm-up time of 25 minutes. Since the Space Station will require gas analysis on a continuous basis, the operating cycle time will be reduced to 95 minutes. Further changes are planned to shorten this to a 30-minute organic analysis cycle. Since the CO hardware is complex and expensive, its removal will increase system reliability and decrease the production cost of the TGA. The Space Station could use a continuous infra-red monitor utilizing the TGA's sampling and data subsystems. A continuous CO measurement could provide a greater margin of safety for Space Station astronauts.

The next step in the development of the Space Station atmospheric monitoring system should include several major tasks. The completion of the data subsystem requires a system level specification describing the TGA/Space Station interfaces and the data system functional requirements. Final specifications are also needed for instrument sensitivities, response (or cycle) times, and power, weight, size, and other engineering parameters. A sampling system must be designed and a flight CO monitor designed using concepts from other closed atmosphere monitors such as the submarine atmosphere monitor. These activities can all be accomplished on the same

schedule as currently proposed for development of the Space Station.

Table 1. Test Gas Mixture

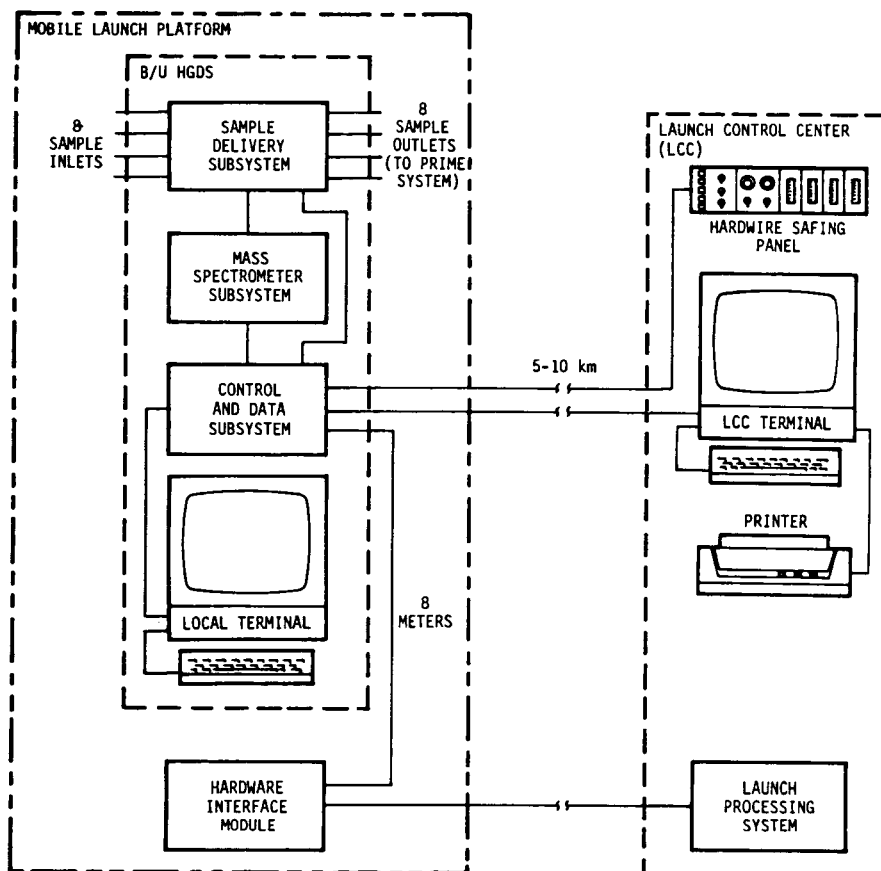
Propanol  
Ethyl Acetate  
Isopropanol  
Benzene  
Methyl Isobutyl Ketone  
Dioxane  
Mesitylene  
Dichlorobenzene  
Carbon Tetrachloride

J. David Collins, 867-4438  
William R. Helms, 867-4438

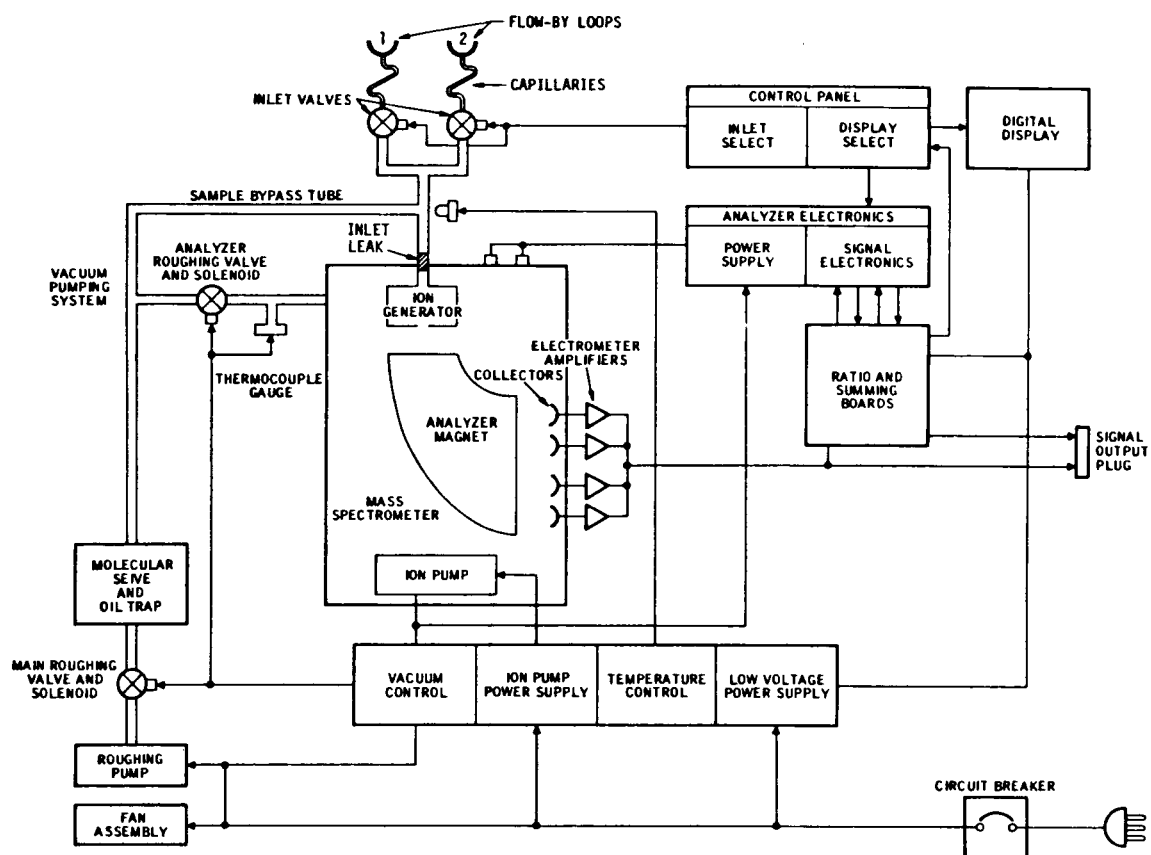
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## Backup Hazardous Gas Detection System for Launch of Space Shuttle and Other Hydrogen/Oxygen Propellant Systems

A mass spectrometer gas analysis system was developed as a backup monitor for sensing potential hydrogen and oxygen leaks during the assembly, test, and fueling phases of the Space Shuttle propulsion system. The system, known as the Backup Hazardous Gas Detection System or B/U HGDS, sequentially monitors any or all of five sample lines connected to the Space Shuttle aft, payload bay, midbody, ET inter-tank, and H<sub>2</sub> Tail Service Mast. The system can be used in the event of a failure of the primary monitoring instrument. It can also operate in a parallel mode, monitoring any one of eight sampling lines continuously, while the primary system is on-line. The B/U HGDS consists of a modified commercial Perkin-Elmer Multiple Gas Analyzer (MGA 1200), integrated with an automated gas sampling system capable of maintaining continuous gas flow in all lines and automatically calibrating each of the gas species monitored. The number of sampling lines and the sampling time are entered via a keyboard and display, along with other control parameters. Zero, span, and test gases are provided to set the gain and then verify the calibration of the individual channels. The MGA 1200 is config-



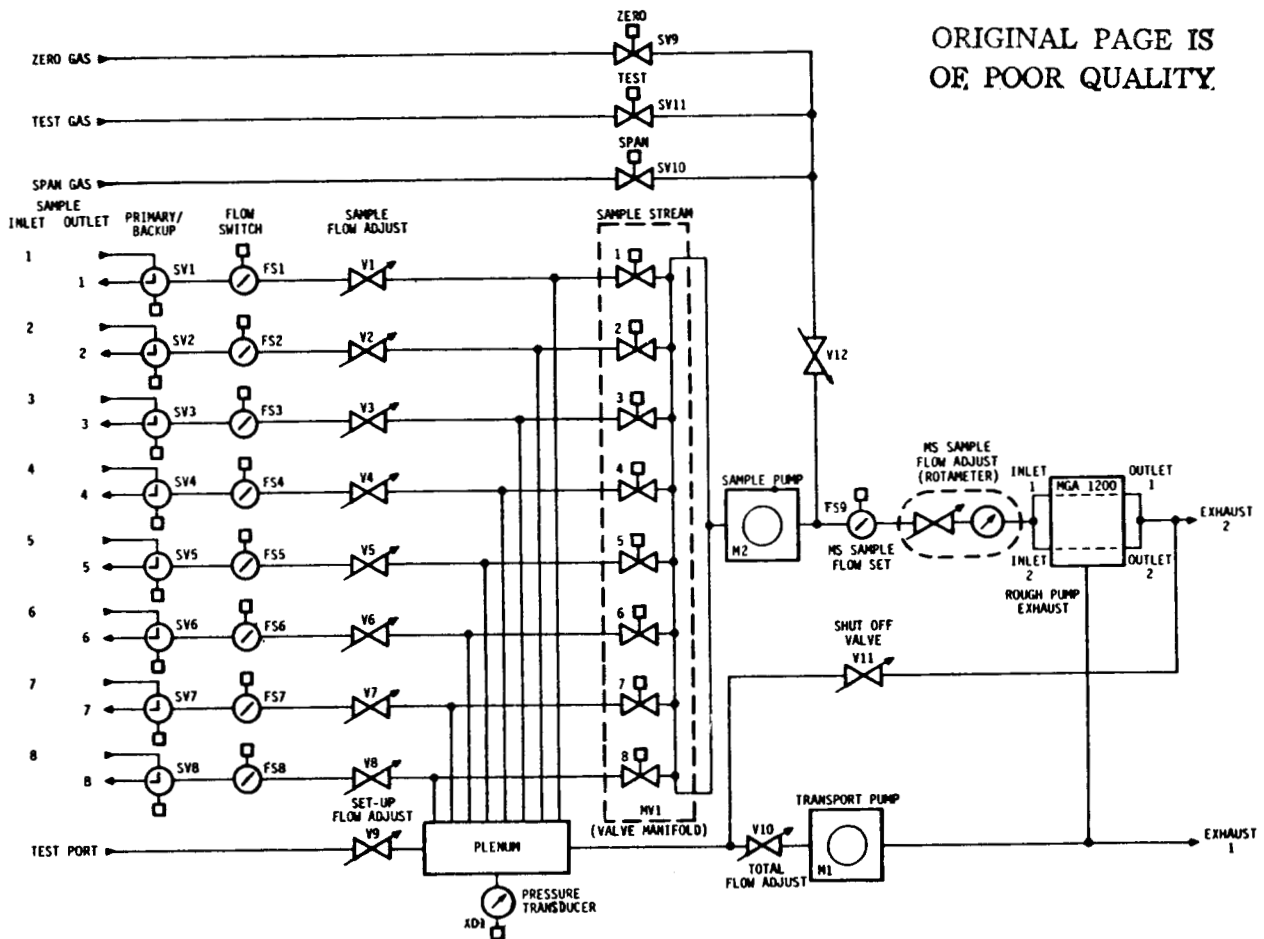
B/U HGDS System Block Diagram



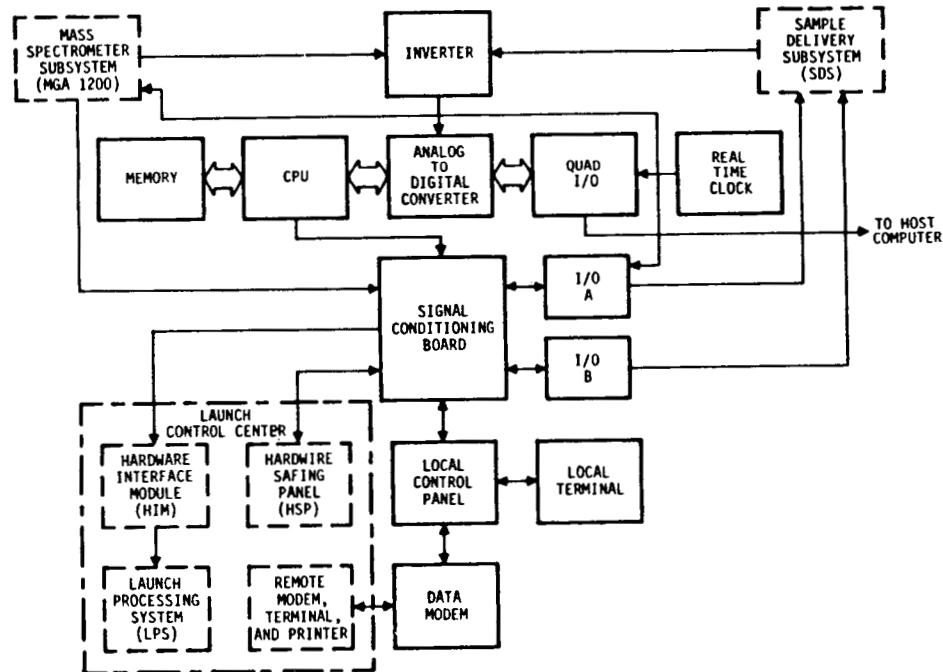
MGA 1200 Subsystem Block Diagram

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Sample Delivery System Flow Schematic



Control and Data Subsystem Block Diagram

ured to analyze for trace levels of hydrogen, helium, oxygen, and argon in a nitrogen background.

The B/U HGDS systems are installed in each of the Mobile Launch Platforms at NASA's Kennedy Space Center to support Space Shuttle launches, at the Western Test Range's Space Shuttle Launch Facility at Vandenberg Air Force Base, and at Kennedy Space Center's Launch Complex 36, where it serves as the primary hazardous gas detection system for fuel loading tests of Centaur rocket boosters used for Atlas-Centaur launch vehicles.

J. David Collins, 867-4438  
William R. Helms, 867-4438

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## Advanced Hazardous Gas Detection System

The Hazardous Gas Detection System (HGDS) monitors the Space Shuttle for potentially dangerous cryogenic leaks. The HGDS has performed very well from its inception in 1979. Manufacturers' support for the HGDS will not be available by 1990 on most of the system and is already unavailable on parts of the HGDS at this time.

In order to fulfill the Space Shuttle's requirement for a highly reliable and well supported gas detection system, the Advanced Hazardous Gas Detection System (AHGDS) project began. The Navy's Central Atmospheric Monitoring System (CAMS) was chosen as a basis for the AHGDS sensor. The mass spectrometer in the CAMS is a rugged, reliable, and accurate magnetic sector instrument. It has been proven in many years of use aboard hundreds of submarines. This mass spectrometer was modified to meet NASA requirements and has undergone extensive testing. Its accuracy, linearity, and stability have been demonstrated in over a year of testing.

This sensor meets NASA's requirements in all but one area. A Helium signature leak check is made on the Space Shuttle Main Engines (SSME) prior to use. This leak check assures that no leaks exist in engine areas that cannot be monitored by the HGDS during normal countdown operations. This leak check requires a helium sensitivity in the area of 2-3 parts per million (ppm). The current AHGDS mass spectrometer is only capable of measuring 5 ppm.

New electrometers for the mass spectrometer were designed and tested but failed to yield significant improvement. The AHGDS mass spectrometer is now being modified to accept a turbomolecular pump as its high-vacuum source. The turbomolecular pump was tested for vibration susceptibility and survived under simulated launch vibration. This pump is expected to lower the gas background noise and, thus, raise system sensitivity.

Design of the AHGDS sampling system and computer control system are currently under way. A fault tolerant sampling system will be utilized to provide additional system reliability. The computer control system will monitor all mass spectrometer and sampling system health check instrumentation to assure proper system operation.

Mark Nurge, 867-4438  
J. David Collins 867-4438  
William R. Helms, 867-4438

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## An Evaluation of a Turbomolecular-Pumped Quadrupole Mass Spectrometer for Hydrogen Leak Detection

The Space Shuttle Utilizes liquid hydrogen and oxygen as propellants for its main engines. The cavities in the umbilicals which carry the liquid hydrogen fuel are purged with helium to inert the area around the potential hydrogen leak point and to carry away leaking hydrogen. The umbilicals are purged with helium rather than nitrogen as nitrogen would become liquid at the extremely low temperature of the liquid hydrogen ( $-423^{\circ}\text{K}$ ). The umbilical cavities are monitored for hydrogen leakage to ensure that a hazardous concentration of hydrogen does not build up in the cavity.

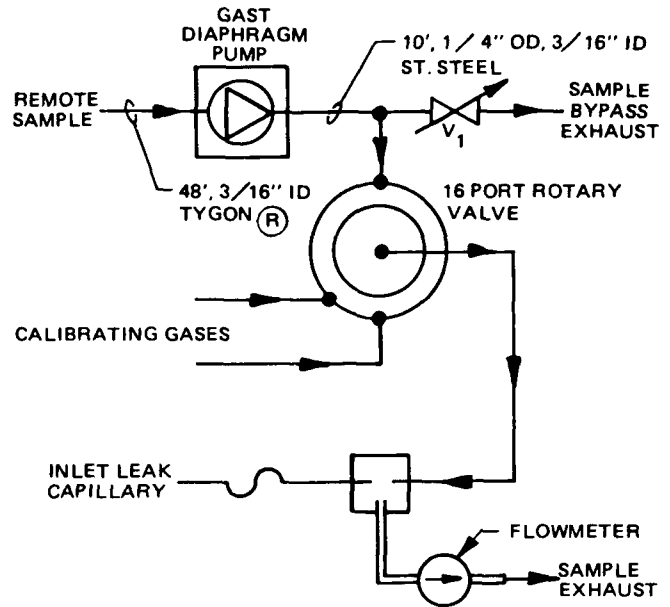
The current umbilical monitoring system uses catalytic combustion sensors which detect and give information about only the hydrogen concentration in the gas sample. These sensors have limited dynamic range and do not provide information about any of the gas stream's other constituents.

The Hazardous Gas Detection System (HGDS) was designed to monitor the Space Shuttle for oxygen and hydrogen leaks in the nitrogen background purge.

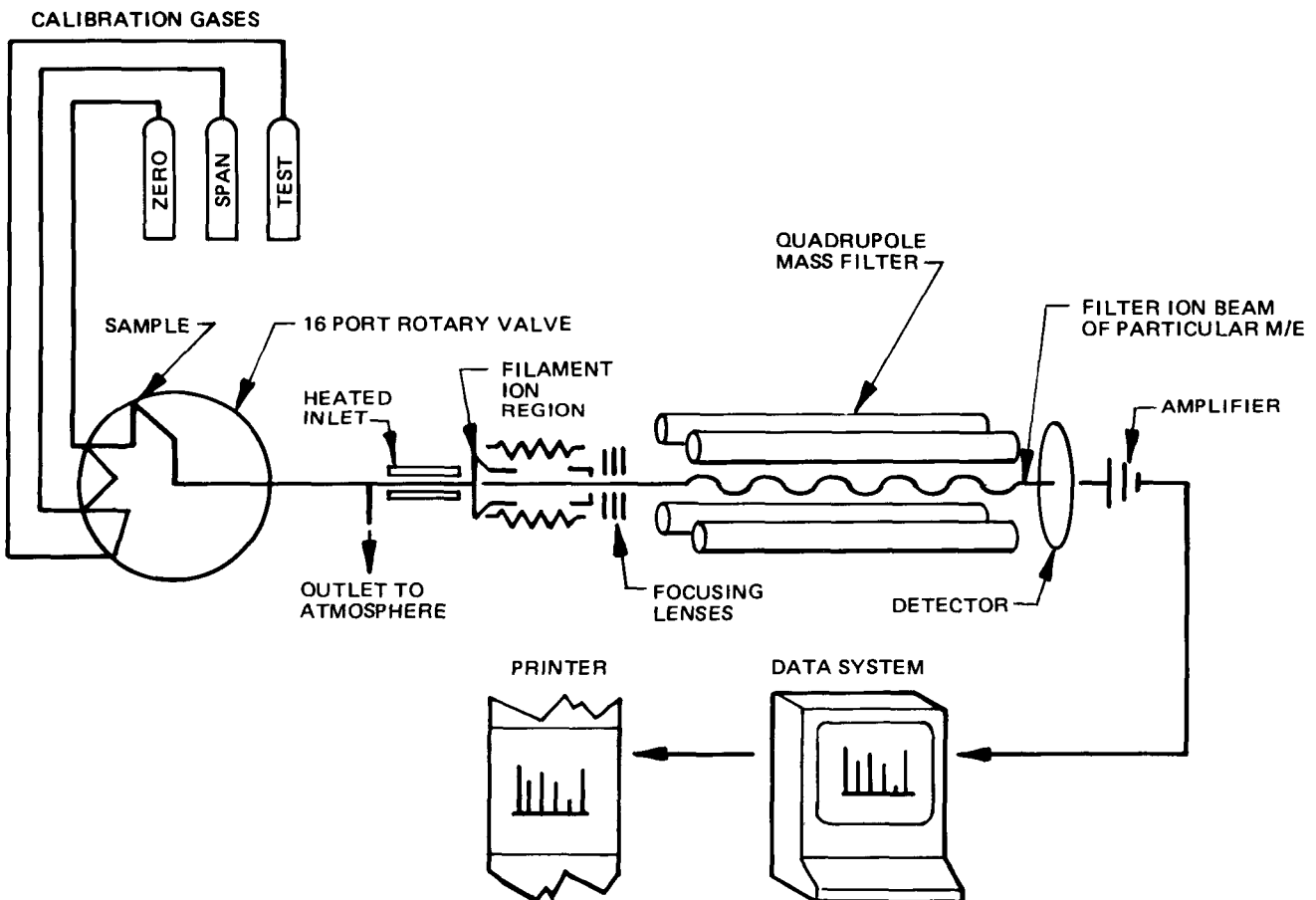
The HGDS can monitor gases in a nitrogen background but is not capable of monitoring gases in a helium background for extended periods of time. The HGDS can give information about the complete make-up of the sample stream. This allows hazard assessment of the leak so that proper corrective action can be taken.

The optimum sensor would have the capabilities of both the catalytic combustion and the HGDS. It would monitor the gas stream for all constituents in a helium gas background. A turbomolecular-pumped mass spectrometer is capable of meeting these desires.

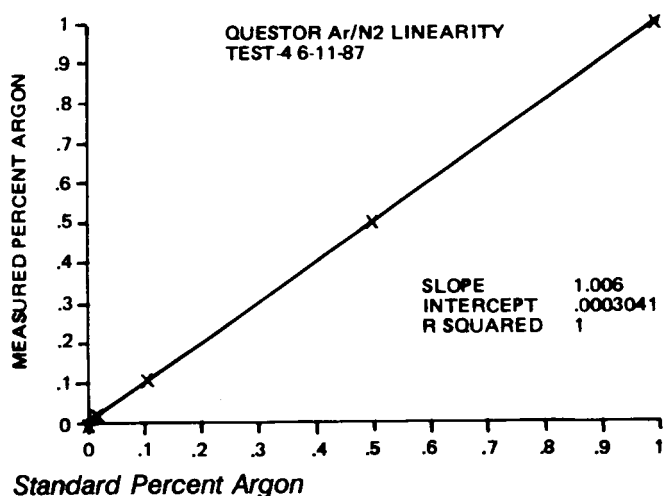
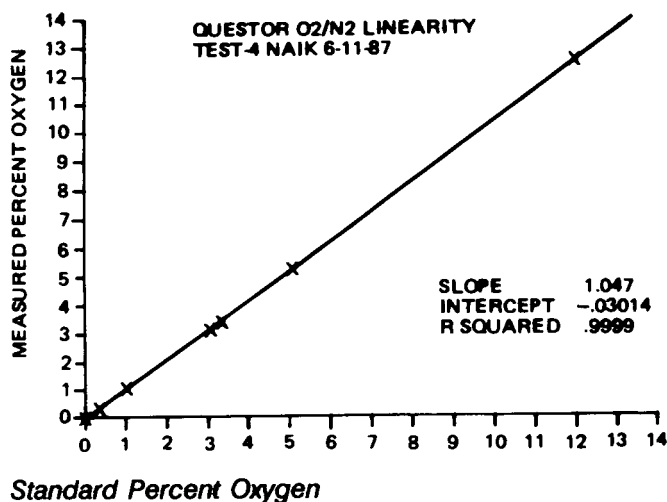
The Extrel Questor is a turbomolecular-pumped quadrupole mass spectrometer. The HGDS is also a quadrupole but uses an ion pump to maintain its high vacuum region at proper operating pressure. The turbomolecular pump allows the Extrel to sample gases in either a nitrogen or a helium background. The Extrel was recently evaluated by KSC for potential use as a hydrogen umbilical monitor.



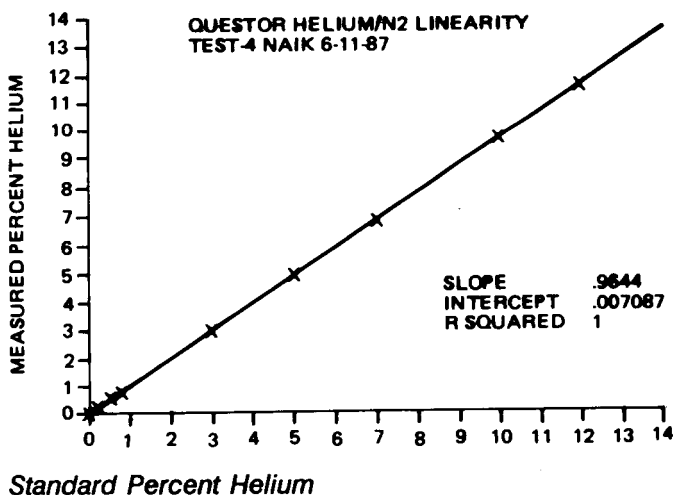
*Sample Transport System for the Questor Process Analyzer*



*Operation of Questor Mass Spectrometer*

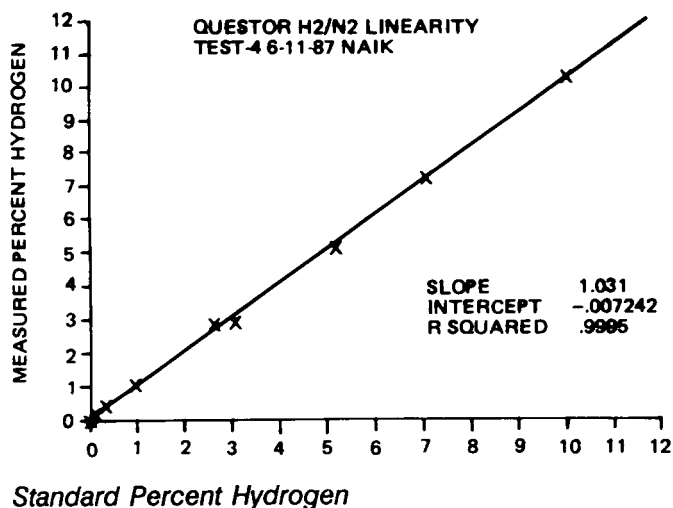


The Extrel unit was tested for accuracy, linearity, precision, detection limits, and zero and span drift. The Extrel exhibited linear behavior in sampling gas streams containing hydrogen, oxygen, and argon in both nitrogen and helium backgrounds. Maximum of 10% error was observed in a span from a few hundred parts per million to up to 12 percent of the gases of interest. The Extrel also demonstrated detection limits of 100 ppm or better for all tested gases.



Mark Nurge, 867-4438  
J. David Collins, 867-4438  
William R. Helms, 867-4438

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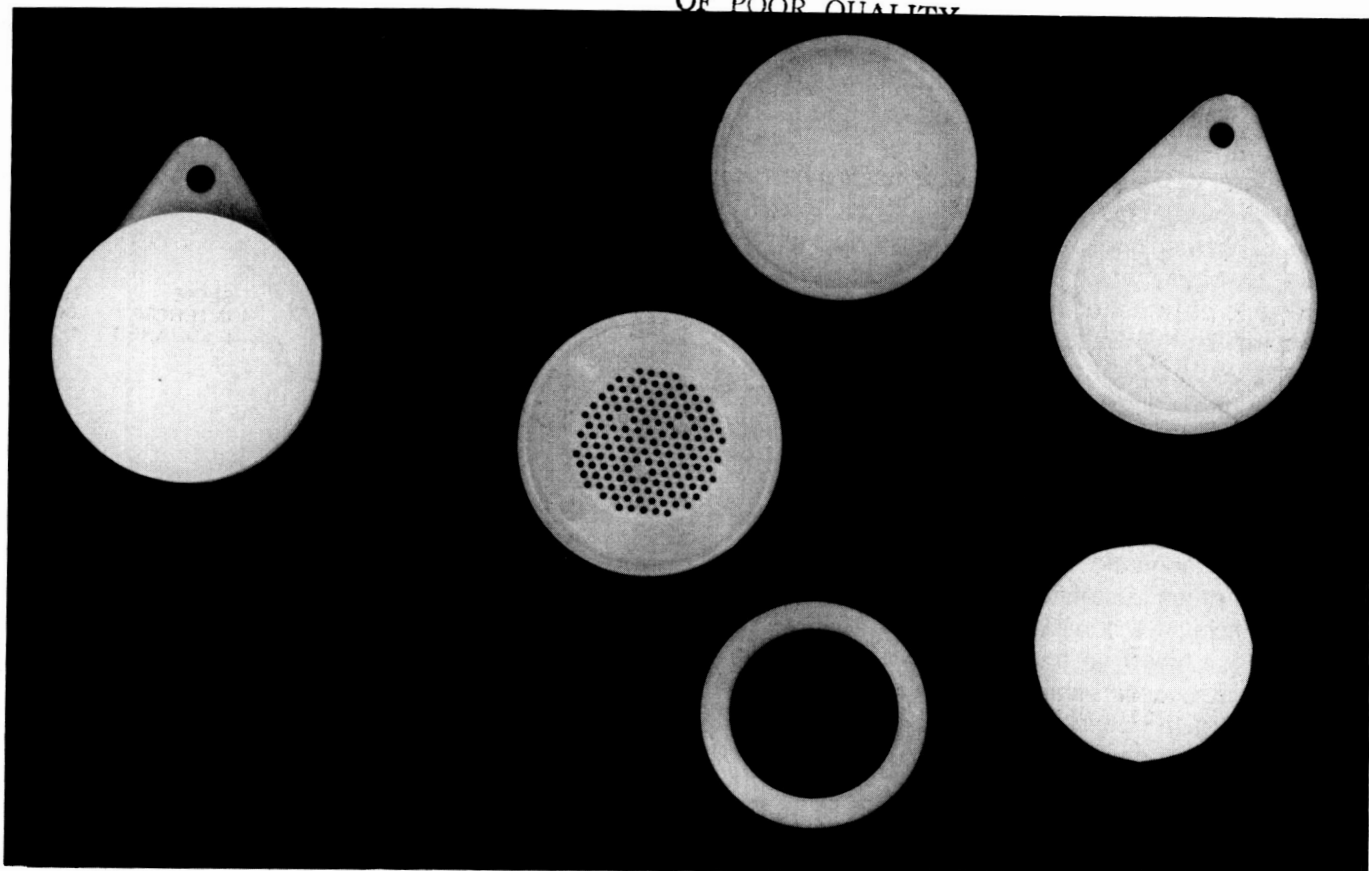


## Quantitative Hydrazine Dosimetry

**Objective:** To develop a passive dosimeter system applicable to personnel and area monitoring of hydrazines in ambient air at the part-per-billion level.

**Background:** The potential carcinogenicity of hydrazines has caused concern for the health and safety of the workers that may come in contact with them. Monitoring of the employees and their work places should be conducted to ensure their exposures remain below the defined levels. A small, inexpensive, passive dosimeter that could be distributed to a large number of personnel to quantitatively monitor their exposure would be useful.

**Approach:** A passive dosimetry badge design was selected in which the collection rate is controlled by the rate of diffusion through a barrier and is independ-

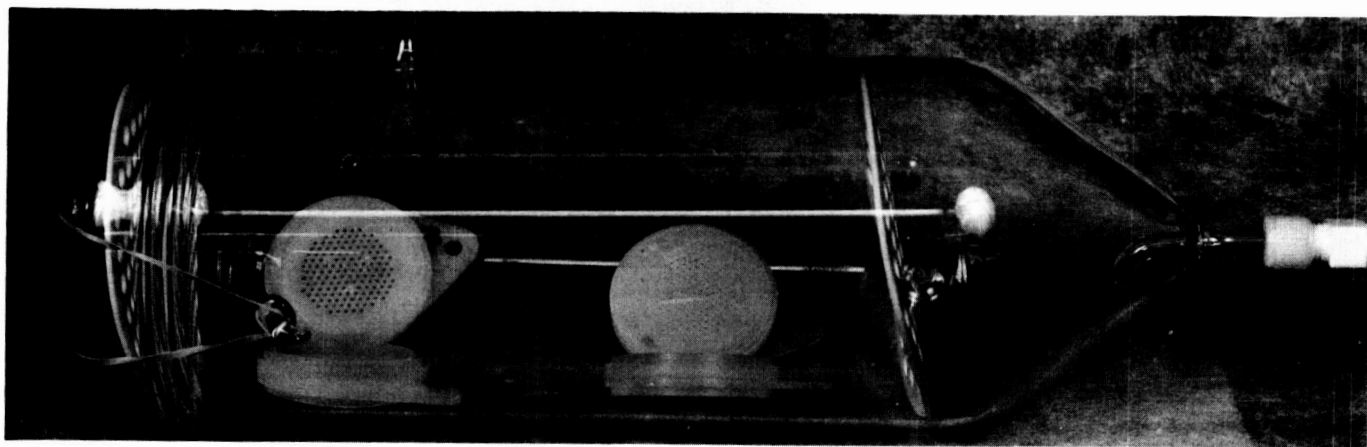


*Dosimeter Badge*

ent of the face velocity. The analyte is then trapped on an organic acid-coated collection disk where it is stabilized for later analysis by coulometry or colorimetry.

Exposure duration, relative humidity, face velocity, and storage stability were investigated.

Results: The dosimeter design consisting of a molded badge housing, diffusion barrier, and an organic acid collection medium provides quantitation of exposure when analyzed by the NIOSH colorimetric method or a coulometric titration procedure. The diffusion barrier containing 144 one-millimeter diameter



*Badge Test Chamber*

holes establishes a collection rate of approximately 30 ml/min. It serves the function to minimize face velocity effects while retaining a threshold limit value (TLV) detection limit of 10 minutes.

Assembly of the new polyethylene molded badge is simplified by its ability to be securely snapped together. The resulting badge is durable, inexpensive, and lightweight, which are desirable qualities of a disposable personal dosimeter. The accuracy of data collected with this badge is within 25% of actual values. The dosimeter has demonstrated accuracy for up to 65 hours of sampling monomethylhydrazine (MMH) at TLV concentration (200 ppb) with minimal interference effects from ammonia, freons, and isopropyl alcohol.

A new colorimetric dosimeter has given qualitative hydrazine measurements in 15 minutes for TLV levels of MMH in relative humidities (RH) of 0 to 55 percent. It has also shown no interference from ammonia. A potential use of the color badge, in combination with the quantitative dosimeter, would be as an indicator for exposure to determine when the latter should be removed and turned in for analysis.

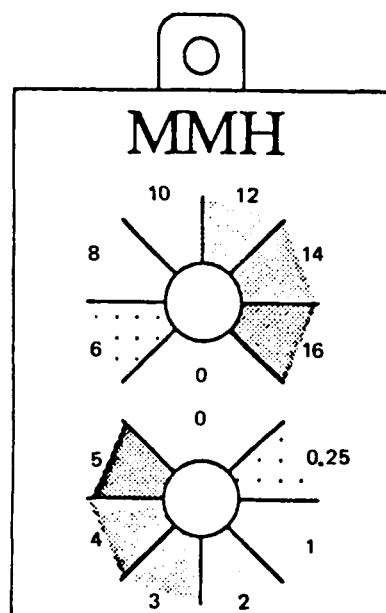
J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Colorimetric Hypergolic Fuel Dosimeter Badge

**Objective:** To conduct basic research to determine the feasibility of producing a passive, badge-type, colorimetric dosimeter for the detection of the hydrazines. The target requirements were low cost, reliability, stability, freedom from common interferents, and ease of use.

**Background:** The use of hydrazines in aerospace, military, and commercial applications has increased the risk of exposure to this carcinogenic chemical. The development of a passive monitoring device that can be worn and read by the worker potentially exposed to the hydrazines would provide an increased margin of safety to bridge the gap between no personal monitoring and expensive instruments which require Safety/Environmental Health personnel to operate.

**Approach:** Using passive diffusion and diffusion barriers as the mode of sampling, the plan is to iden-



*Colorimetric Hypergolic Fuel Dosimeter Badge*

tify suitable colorimetric, chemical-reaction systems and to characterize the most appropriate candidate system for sensitivity to the hydrazines, color stability in various environments, effects of temperature, humidity, interferences, and long-term storage stability.

**Results:** Three candidate systems have been identified and preliminary investigations have indicated a high probability of success in this study. Continuing work will aim toward badges for field testing in FY 88.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Photoionization Hypergolic Fuel Vapor Detector

**Objective:** To develop a small (flash-light size) photoionization detector (PID) for TLV concentrations of the hydrazines.

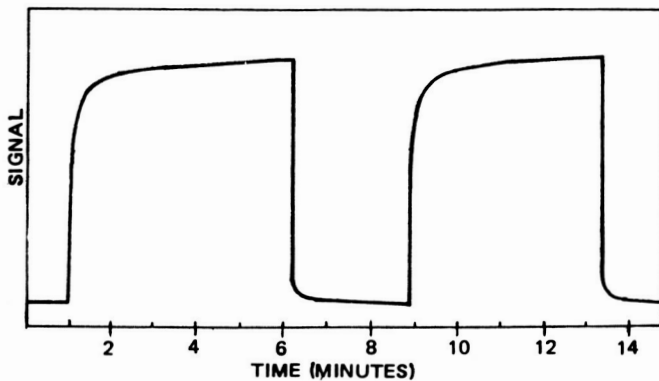
**Background:** Portable, low-level hypergolic fuel vapor detectors currently available are based on electro-chemical reactions. These sensors will be unable to detect the projected TLV levels and there are no portable alternatives available at this time.



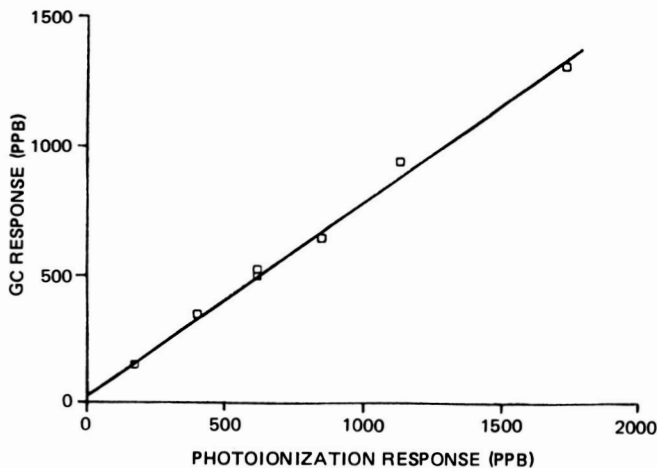


ORIGINAL PAGE IS  
OF POOR QUALITY

*Prototype Instrument*



*Instrument Response to 5 ppm of MMH*



*Instrument Linearity*

**Approach:** A commercially available, hand-held photoionization detector will be modified in order to make it sensitive to the hydrazines. Laboratory tests will then be performed to enhance the electronics, ionizing source, and sampling system in order to optimize the detector for hydrazines.

**Results:** Initial results indicate the PID works well for UDMH. It is highly specific, sensitive, linear, and relatively free from interferences. More work is needed for hydrazine and MMH with improvements in packaging and sensing mechanisms.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Solid-State Electrochemical Sensors for Hydrazines

**Objective:** To test and evaluate various sensors based upon solid ionic conductors for sensitivity to the hydrazines.

**Background:** Electrochemical sensors currently available for the detection of the hydrazines use a wet, highly caustic electrolyte (usually KOH). A hydrazines sensor using solid ionic conductors would eliminate problems associated with wet electrolytes such as

leakage, evaporation, carbonation, and orientation sensitivity.

**Approach:** Screen a number of potential ionic conductors and perform laboratory tests on those determined to be the most promising in amperometric sensor geometries.

**Results:** Initial results have indicated several problems such as slow response, extreme humidity, flow sensitivity, and signal degradation. Further testing is currently in work.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Comparative Evaluation of Toxic Vapor Sensors

**Objective:** To test and evaluate technologies suitable for monitoring hydrazine at the parts-per-billion (ppb) level. The three promising technologies are: 1) chemically doped paper tape, 2) chemical derivatization followed by chemiluminescent detection, and 3) photoionization.

**Background:** The results of prior evaluations demonstrated that none of the existing technologies for hydrazine detection totally meets NASA objectives for reliability, stability, and selectivity. Therefore, new, yet unproven, technologies will be investigated to determine if a suitable instrument can be developed.

**Approach and Results:** Three technologies being investigated:

1. Chemically doped paper tape. The results of prior evaluations showed that paper tapes were capable of selectively determining hydrazine at the ppb level. However, the performance of associated instrumentation was inadequate. New instrumentation utilizing an improved tape transport mechanism has been studied to determine its potential. The instrument was much better than the previous design. Alternative sampling methods are currently being tested to overcome sample line absorption problems.

2. A method of sampling hydrazine by first reacting it with acetaldehyde then detecting the reaction product has been developed by Thermo Electron Corp (TECO), now known as Thermedics. Preliminary studies with hydrazine have shown that the bread-board instrument possesses excellent linearity and accuracy

and has adequate sensitivity. The TECO instrument has been evaluated to determine its limit of detection, accuracy, precision, and long-term reliability for MMH. The performance of the system is limited by the reliability of the derivatization method. An improved prototype will be tested during FY 88.

3. Photoionization appears to be a selective method for hydrazine. Preliminary work with hydrazine and MMH has shown that the technique possesses the necessary sensitivity and dynamic range. In addition, this method appears particularly attractive for use in space operations. A portable photoionization detector has been modified and evaluated for use as a hydrazine detector. At the ppm levels, the instrument is fast, reliable, and has few interferences. For ppb level analysis, much work is needed to reduce the interference effects from other commonly found amines. Two different energy lamps will be tested and a combination of the signal will be investigated to reduce interference effects.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Chemiluminescent Hypergolic Propellant Vapor Detector

A cooperative development effort between NASA, USAF/Space Division, The Naval Research Laboratory, Aerospace Corp., and Thermedics has resulted in the development and modification of a new ambient air monitoring instrument designed specifically for detection of airborne levels of the three hydrazine propellants, hydrazine, monomethylhydrazine (MMH), and unsymmetrical dimethylhydrazine (UDMH). The objective of this work is a fast-response, wide response range, sub-TLV detector for these propellants, with high specificity, ensuring interference-free monitoring at very low vapor levels. The detection method relies on the unique chemistry that occurs between the hydrazine fuel vapors and acetaldehyde. A two-channel fuel vapor detection system based on this chemistry and NO chemiluminescence has been demonstrated to meet many practical detection needs. This technology has now been applied to a multiple-channel system, which monitors for both fuel and oxidizer vapors, and is capable of fully automatic operation.

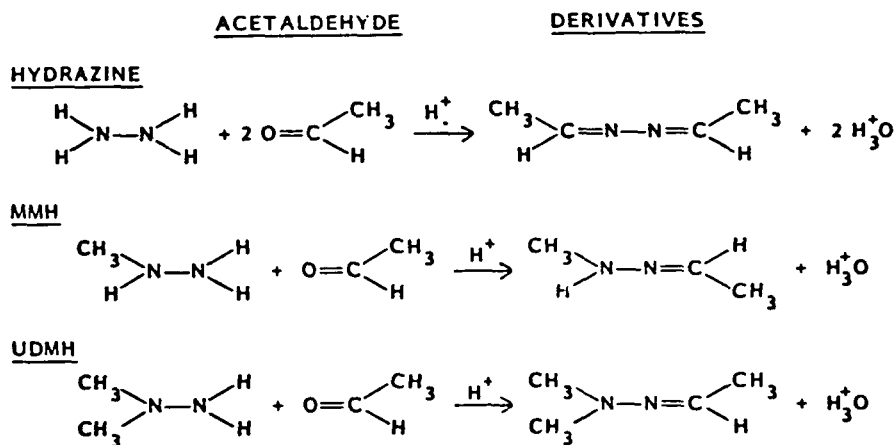
The original system, designed for use on the Titan II and subsequently used on Titan III, was not appro-

priate for measuring hydrazines other than UDMH. It was, therefore, modified to include an acetaldehyde reaction of the hydrazine and MMH to facilitate detection. The basic chemistry of this detection method is shown in the figures "Acetaldehyde-Hydrazine Propellant Reaction Products" and "Oxidation Reactions of the Hydrazine Propellant Aldehyde Derivatives" and Equations 1 through 3.

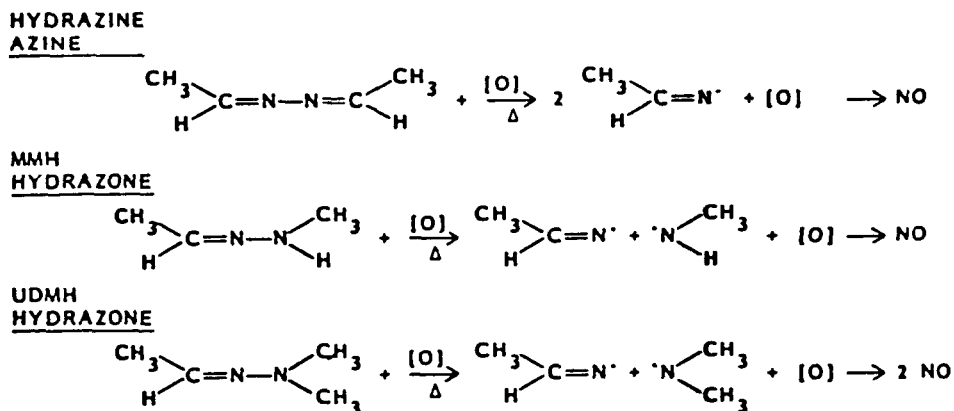
1.  $\text{NO} + \text{O}_3 \longrightarrow \text{NO}_2^*$
2.  $\text{NO}_2^* + \text{M} \longrightarrow \text{NO}_2 + \text{M}^*$
3.  $\text{NO}_2^* \longrightarrow \text{NO}_2 + h\nu \text{ (600 - 1800 nm)}$

The fuel detector consists of two identical channels

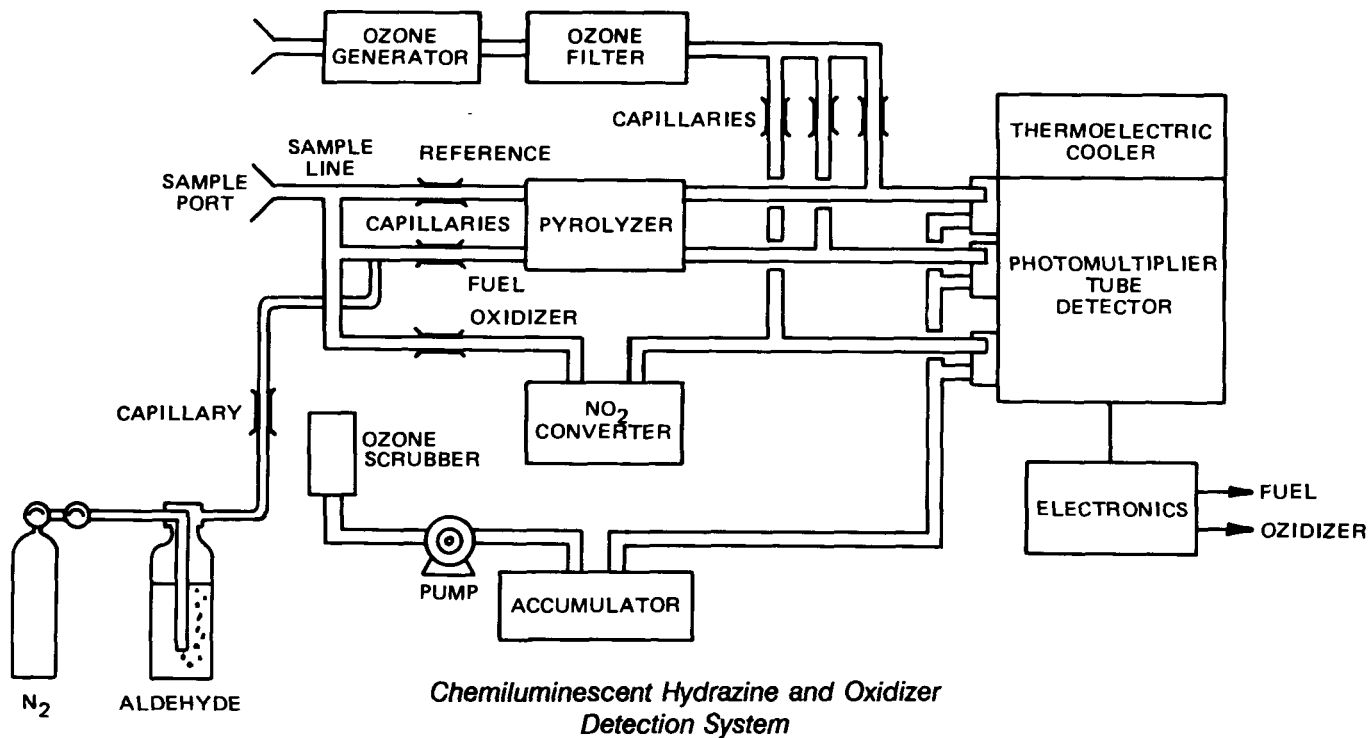
operating at the same temperature and using the same catalyst. Acetaldehyde is introduced into one channel, the NO signal is measured in both channels, and the difference is read as the amount of hydrazines in the sample. Since the reference channel is the same as the original design of the UDMH detector for the Titan II, and the aldehyde reaction produces 2 NO molecules for UDMH as compared to one NO for MMH and hydrazine, the difference in NO response of the fuel and reference channels is nearly equal. Similarly, for samples which do not react with the acetaldehyde and pyrolyzer to produce NO will produce no difference in response. The result is a detector which is sensitive to the target hydrazines and very insensitive to most interferents.



*Acetaldehyde - Hydrazine Propellant  
Reaction Products*



*Oxidation Reactions of the Hydrazine  
Propellant Aldehyde Derivatives*



Thirteen interferences were tested in backgrounds of zero air and one to three ppm of target gas ( $\text{NO}_2$ , MMH or hydrazine in air). The worst case interference was ammonia with an interference ratio of 1/2500. Preliminary results indicate excellent linearity and precision. Functional testing will continue at the Naval Research Laboratory.

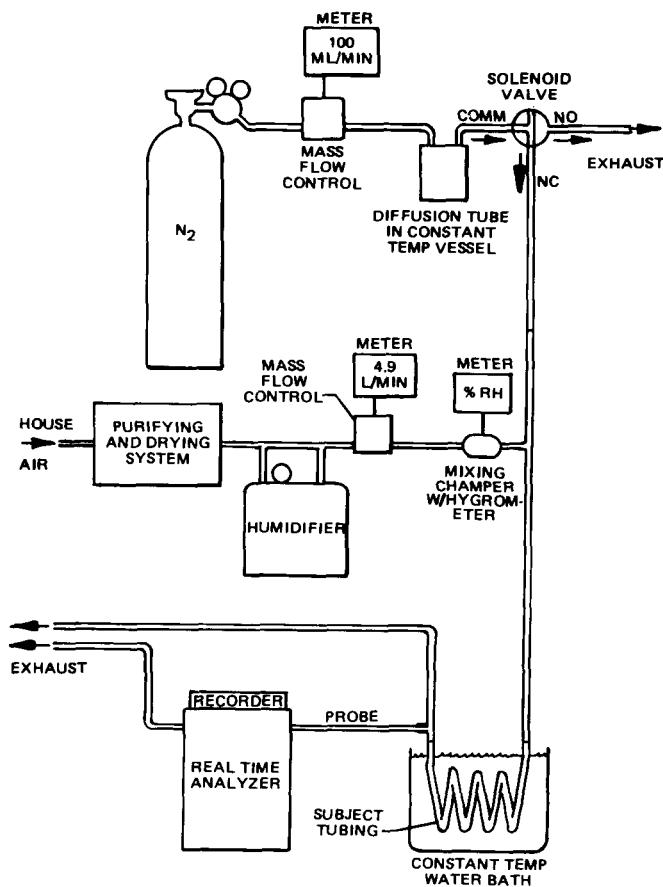
The figure "Chemiluminescent Hydrazine and Oxidizer Detection System" shows the functional block diagram of the Chemiluminescent Detector.

J.C. Travis and William R. Helms, 867-4438  
DL-ESS-31

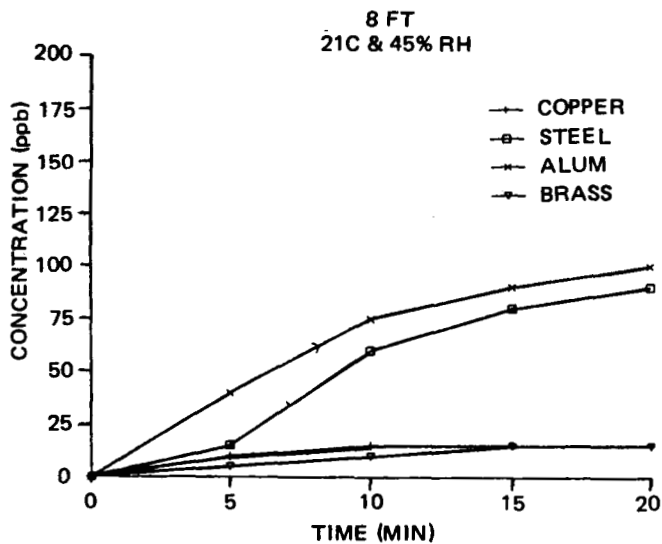
## Evaluation of Sample Line Tubing for MMH Transport

**Objective:** To test and evaluate various sample lines for monitoring part-per-billion (ppb) levels of hydrazines in ambient air.

**Background:** Widespread use of the hydrazines in NASA Aerospace and military applications make air sampling of potentially contaminated areas an important safety consideration. Centrally located monitoring devices and long sample transmission lines (tubing)



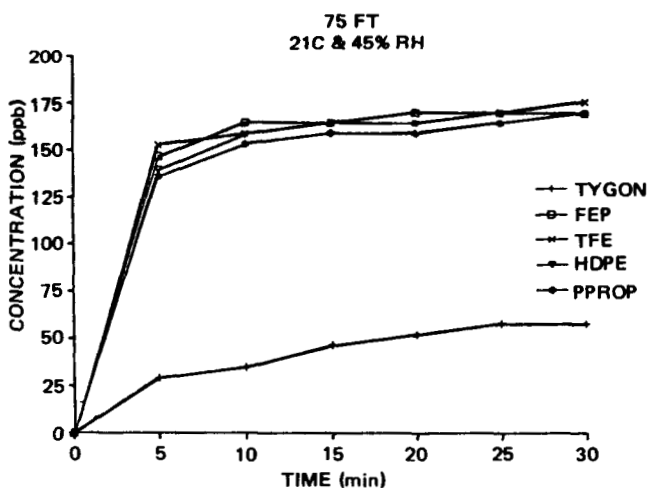
*Schematic of Apparatus Designed for Evaluating Transport Efficiencies of Various Tubings*



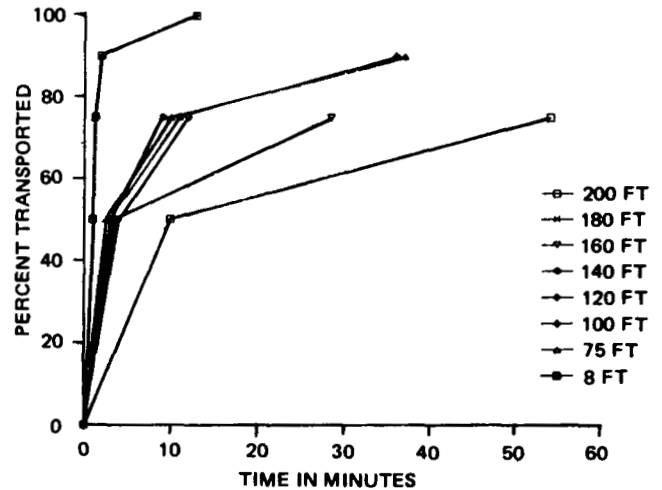
*The Transport of 200 ppb MMH Through Selected Metal Tubes.*

make the choice of tubing material important. Some typically "inert" materials in general chemical handling are not suitable for hydrazine or monomethylhydrazine sampling due to interactions between the tubing and the hydrazine.

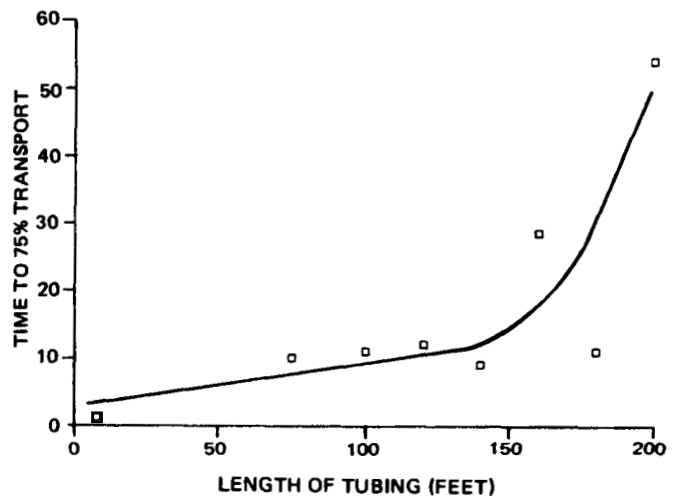
Approach: Tubing of various lengths and cross sectional internal diameters, including some metal and a wide selection of polymeric tubing, were selected for this evaluation. Transmission efficiency was measured with a chemiluminescent detector and was



*The Amount of MMH Contaminated Air Stream Flowing at 51/min Transported Through 75 Ft. of Tubing at 21°C (The Air Stream Contained 45% RH and 200 ppb MMH)*



*The Effect of Sampling Line Length on the Transport Efficiency of a 200 ppb MMH Air Stream Containing 45% RH at 19°C*



*A comparison of the Time Required to Achieve 75% Transport of MMH for Various Lengths of Tubing*

based on rate of transport and maximum percent of MMH transported. Other variables included in this project were temperature, humidity, and the effect of teflon-joined segments. Results of pushing versus pulling the contaminated air stream were also explored.

Results: From the results obtained in the preliminary screening, metal tubing is not recommended. Many of the teflons and polymers proved to be ac-

ceptable candidates, including: Bev-a-line IV, FEP, HDPE, PFA, polyethylene, TFE, and polypropylene. Clean Bev-a-line IV had the best transport properties. Many of the above mentioned candidates had transport times and percentages which would be adequate for some applications. In addition, the Bev-a-line IV exhibited the desired flexibility. Many of the other tubes showed a tendency to crimp.

Temperature and relative humidity have essentially no effect on the tubing selected.

The fate of the MMH which is not transported to the outlet of the tubing lines has not been determined. The exhaust was monitored by the TECO analyzer which would not differentiate between MMH and ammonia, which is a known break-down product. An alternate instrument, the MDA 7100, which is not sensitive to ammonia, NO, or NO<sub>2</sub>, was also used and gave a comparable MMH response. This suggests that break-down is not the reason for the loss. In addition, the sampling line was checked for residual MMH by collecting and concentrating an acetone wash, and analyzing it by gas chromatography. No MMH was detected.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Toxic and Flammable Gas Detectors

**Objective:** To evaluate and report on recently developed versions of low cost, "alarm only" toxic gas and hydrogen sensors.

**Background:** Hydrazines, which are used extensively in various Space Shuttle systems, are highly toxic and corrosive. It is, therefore, necessary to identify leaks and spills as rapidly and accurately as possible. Hydrogen, which is used to fuel the Space Shuttle Main Engines, is explosive at sufficiently high concentrations, hence, it is equally important to identify hydrogen leaks before they reach critical levels.

**Approach:** The improved Figaro TGS 813 and TGS 821 sensors were tested for their responses to both hydrogen and monomethyl-hydrazine (MMH). The background gases for these experiments were GN<sub>2</sub> and air. The effects of potential interferents such as ethanol, NH<sub>4</sub>, and general reducing agents have been evaluated for each sensor type.

**Results:** Both sensors, the TGS 813 and the TGS 821, were unsuitable for use as hydrazine sensors. Their response to changes in relative humidity was greater than their response to the MMH. The TGS 813 testing was discontinued due to its high sensitivity to interfering gases. The TGS 821 was sensitive to hydrogen and relatively insensitive to interfering gases. Testing of the TGS 821 for hydrogen is still in progress.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31

## Multispectral Imaging of Hydrogen Fires

A requirement for a camera that could display normally invisible hydrogen fires was realized during an aborted STS-14 launch. Immediately after the on-pad abort, the hydrogen flame detectors went into alarm condition. During the fire, it became apparent that visibility of the hydrogen fire was highly desirable. Fire extinguishing systems must be turned off to enable the current fire detection system to operate.

Hydrogen fires emit within the same frequency band as sunlight. While sunlight is present, a hydrogen fire is invisible to human eyes and to standard cameras. Hydrogen fires also emit in bands not visible to standard cameras (or eyes) but are visible to specialized sensors. A camera which could display a hydrogen fire and be hooked directly into the standard OTV channels would be a valuable safety device.

As hydrogen flames emit UV and IR, a UV-IR camera would allow visibility of a hydrogen flame. To properly identify the location of the fire and the extent of the action to be taken, it is necessary that a high resolution picture of the background be displayed on the same image as the fire. It is also necessary to provide a way to easily distinguish between the frequencies of interest.

A proof-of-concept version of the camera has been built and tested. It utilizes a slow scan infrared imager modified to add UV and visible light sensors to its receptor area. These signals are then combined in an IBM PC-XT to display a unified image. This configuration is limited in resolution and speed due to the inherent limitations of the scanner and the computer. This unit does demonstrate that the objective of overlaying

## Solid Rocket Booster Inadvertent Ignition Detection System

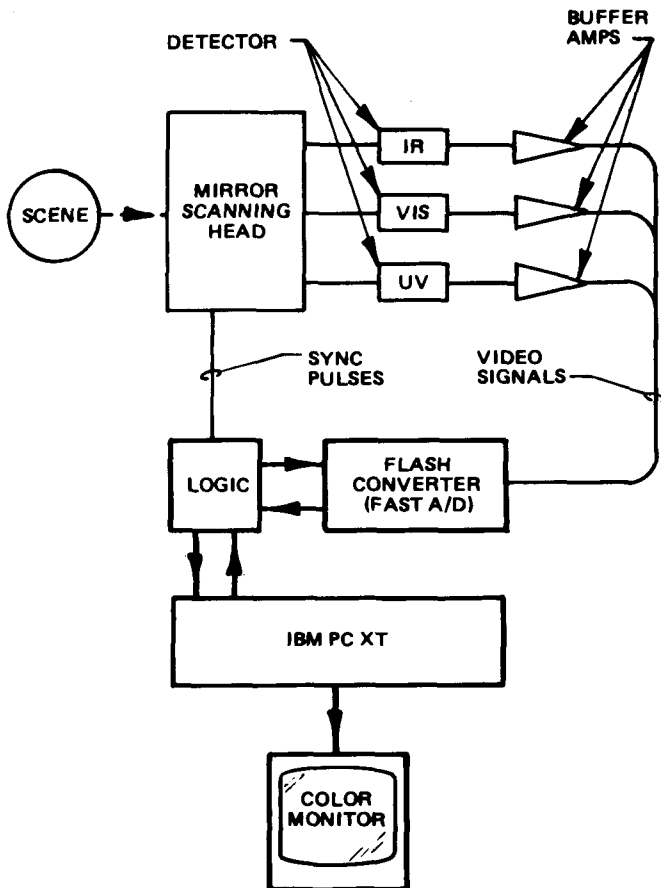
The Solid Rocket Booster Inadvertent Ignition Detection (SRBIID) system originated in response to a safety request for a study on how to detect an inadvertent ignition of a Solid Rocket Booster (SRB) or an SRB segment in the Vehicle Assembly Building (VAB). Upon detection of an ignition, devices would be automatically activated to trigger a ventilation system to reduce facility damage and personnel injury.

The task of detecting a booster ignition was complicated by a requirement for no false alarms and fast response times. This makes the task considerably more challenging. There are arc welders, blow torches, sunlight, and, potentially, occasional small fires in the VAB. A walkdown of the VAB was conducted to observe booster handling procedures and to get an estimate of the maximum detection distance required of the system. One hundred feet was determined to be the maximum distance a detector would be located from the SRB segment in the VAB.

In order to meet the no false alarm requirement, an overlapping, multispectral zone system was decided upon, consisting of ultraviolet, infrared, and visible light detectors with the outputs feeding into a voting logic circuit needing a positive signal in multiple zones to issue the alarm. A prototype system was fabricated utilizing fast-response flame detectors, remote infrared (heat) detectors, and visible light detectors.

The system was tested for possible interferences using sunlight, arc welders, blow torches, small butane flames, and infrared heat sources. The system was then taken to Morton Thiokol, Utah for testing during the firing of Demonstration Motor-8 of the newly designed SRB. The system was installed approximately one hundred feet back from the nozzle at a forty-five degree angle. The system performed successfully during the static firing. System data was recorded and analyzed for several dry runs and static firing.

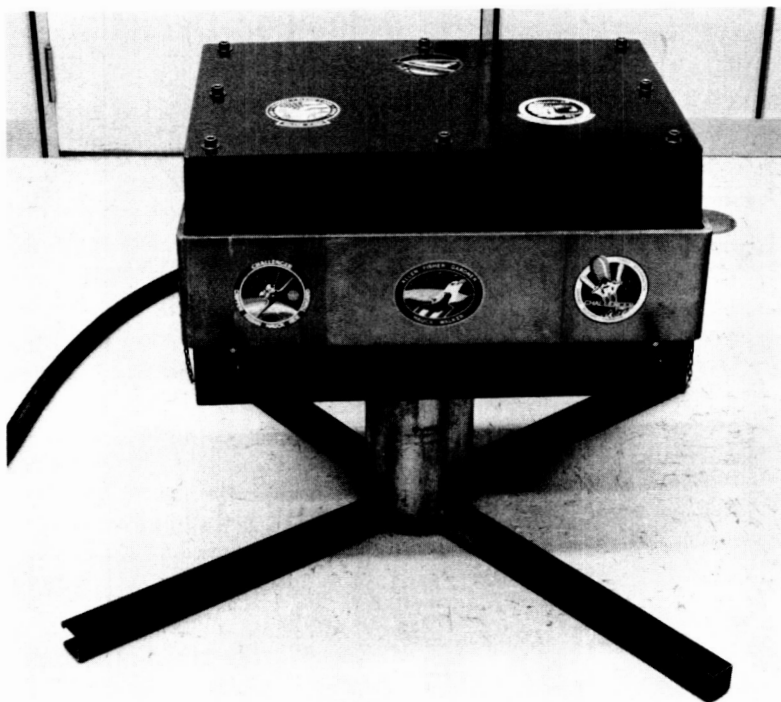
The data received indicates that the proposed system requirements can be met. Responses were recorded in all frequency bands. Several sensors demonstrated rapid response times and good selectivity. Further development will include integration of



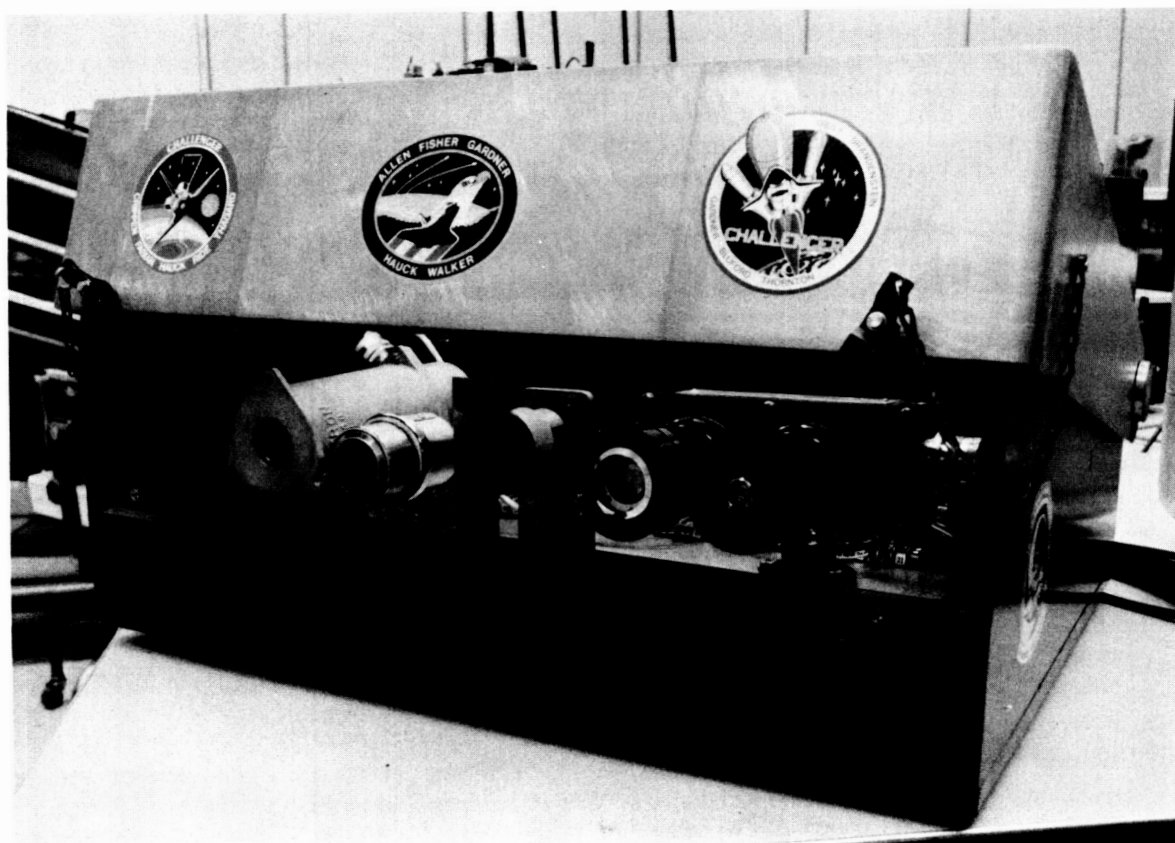
*Block Diagram of Multispectral Scanner*

a high-resolution video image with UV and IR signatures is feasible.

Current plans entail the display of the visible light spectrum as a high-resolution, black and white picture. The IR and UV components would then be overlaid as red and blue (respective) images. This would allow visibility of the actual flame, as well as its associated heat plume, on a clearly recognizable background. This system needs to display the processed images in real time to meet operational requirements. To build this system, faster sensors and video processors have been ordered and new software is being written. Image intensification technologies are also being studied for the UV channel, as hydrogen flames emit rather weakly in this spectrum outside of the bands where sunlight emits.

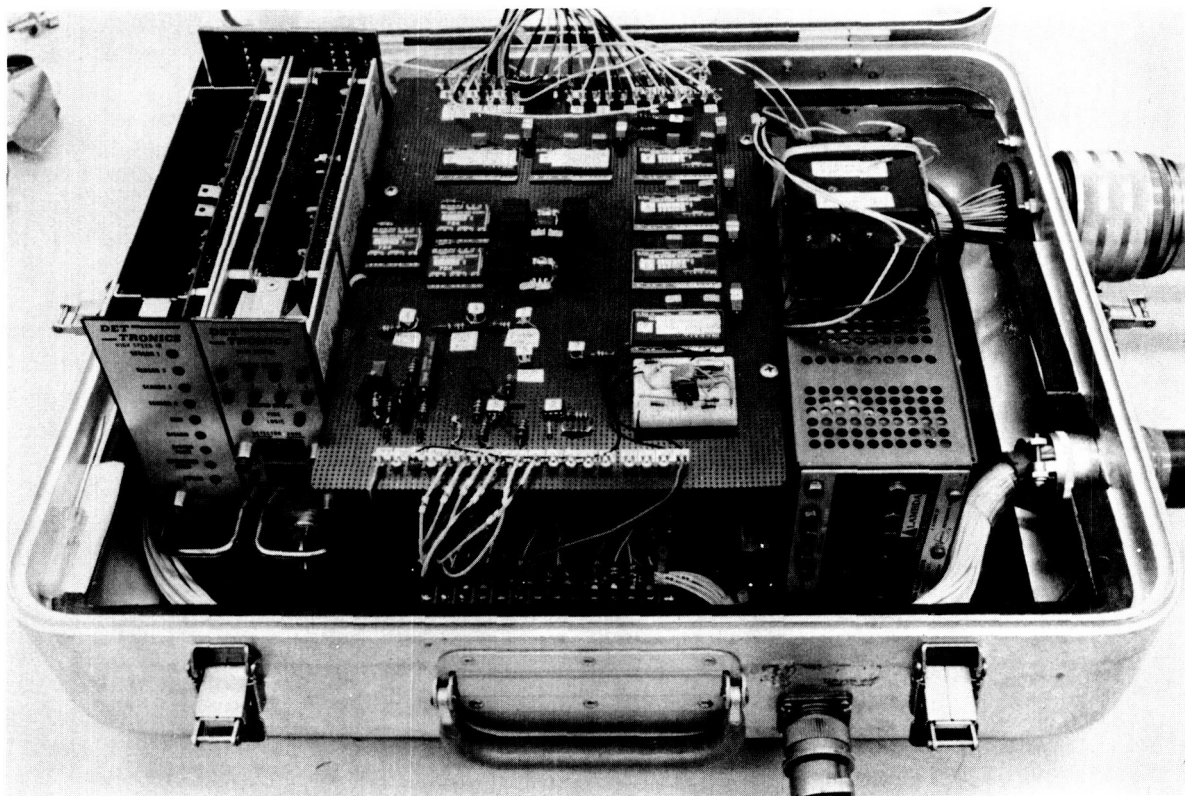


*SRB Inadvertent Ignition Detection System*



*Sensor Array*





*Signal Conditioning*

the logic circuitry and reducing the signal conditioning response time.

J. David Collins, 867-4438 DL-ESS-31  
Julie E. Baker, 867-4438 DL-ESS-31  
William R. Helms, 867-4438 DL-ESS-31

## **Remote Detection and Characterization of Fugitive Hydrogen by Raman LIDAR**

The objective of this project is to develop and field test a Raman Light Detection and Ranging (LIDAR) system which is capable of three-dimensionally mapping and characterizing fugitive hydrogen clouds associated with SSME ground firing operations.

Routine launch pad preflight combustion testing of the Space Shuttle Main Engines is immediately followed by the purging of invisible, unburned hydrogen which has a finite potential to build up in open areas where traditional fixed-point detectors cannot be installed. The primary advantage of remote sensing instrumentation lies in its ability to scan large spatial

volumes of the atmosphere surrounding facilities, from one or more centrally located positions, providing thousands of cubic meters of monitored area protection unobtainable with currently available instrumentation.

Operating in many respects similar to radar, LIDAR employs a pulsed laser as transmitter and a photomultiplier-equipped telescope as a receiver. Pulsed laser energy propagates through the atmosphere along the telescope line of sight, radiating (exciting) all molecules along the path. Most molecules (including  $H_2$ ,  $N_2$ ,  $O_2$ ) scatter electromagnetic radiation not only at the excitation wavelength, but also at specific (shifted) wavelengths, by the phenomenon referred to as Raman scattering. The magnitude of the wavelength shift is unique to the particular scattering molecules (in this case hydrogen). The intensity of the Raman band is proportional to the scatter originally caused by the pulsed laser radiation of molecules of measurement interest received back at the LIDAR system telescope, which is "tuned" through the use of special band pass filters to the Raman wavelength of the molecule of interest.

In this initial phase of the program, an existing

Raman Mobile LIDAR System is being modified and optimized to detect and measure hydrogen. The system will be used in field tests at the NSTL engine test facility where it will be stationed between 1,000- and 2,000-foot distance from the SSME test stand exhaust deflector, and scanned through the boundary layer of the SSME plume. The NSTL LIDAR field program is expected to provide previously unobtainable data on SSME plume hydrogen, as well as assess the need and feasibility of using LIDAR to routinely monitor KSC ground firing operations.

Mark Nurge, 867-4438  
 Chuck Griffin, 867-4438  
 William R. Helms, 867-4438  
 J. David Collins, 867-4438

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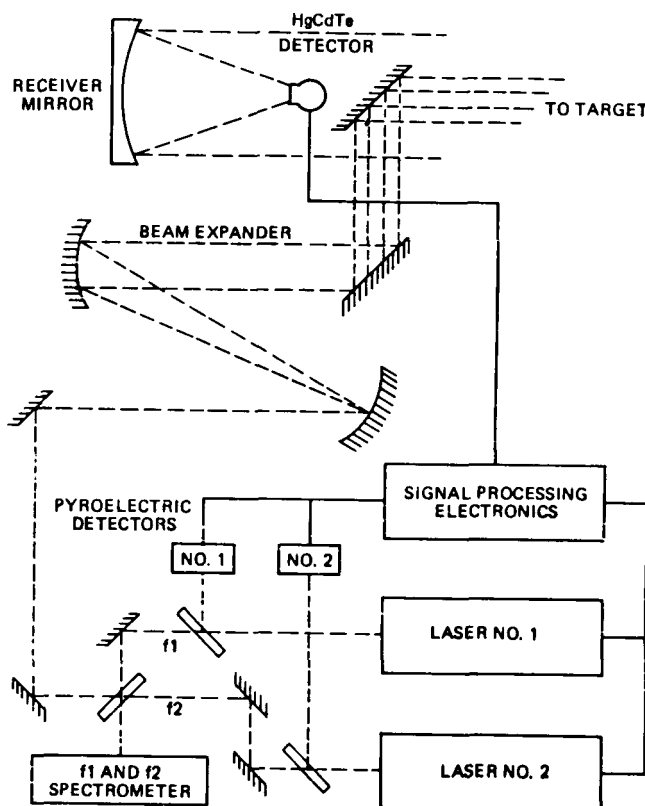
## Remote Sensing of Hydrazine

A laser remote sensing instrument has been fabricated and delivered to the Kennedy Space Center (KSC) by the Jet Propulsion Laboratory (JPL). JPL performed the research that determined the instrument design as the initial phase of this project. In the next phase, JPL fabricated and tested the instrument to verify the concept. This prototype system is designed for the detection of the hydrazine, mono-methylhydrazine, unsymmetrical dimethylhydrazine, and ammonia remotely to a distance of 250 m. The key elements of the system, shown in the figure "Laser Remote Sensing System," are a pair of rf-excited, grating-tuned waveguide CO<sub>2</sub> lasers, a beam expander, an f/1 receiver mirror, a mercury-cadmium-tellurium (HgCdTe) detector, and signal processing electronics.

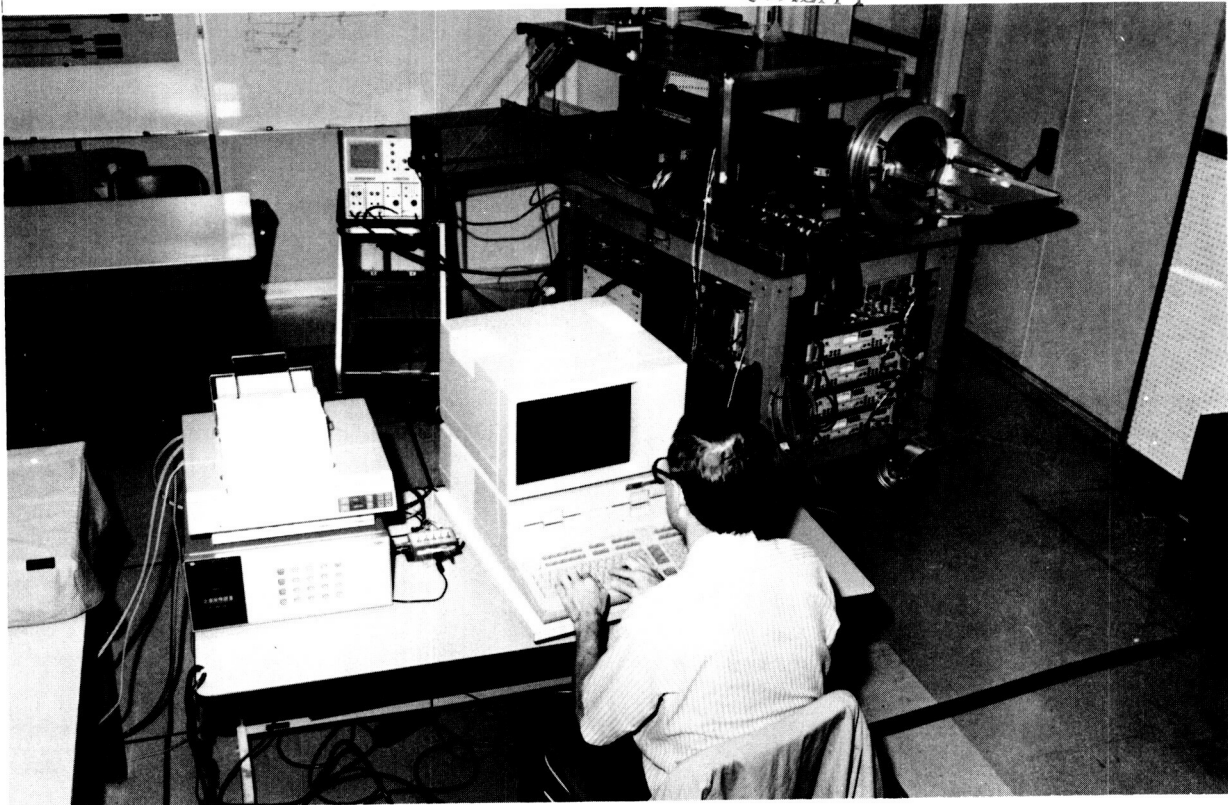
The instrument uses the differential absorption lidar (DIAL) technique for detecting the above vapors. Each laser is tuned to the appropriate set of wavelengths, one to the wavelength that the vapor of interest absorbs in the infrared (IR) energy band, and the other one to a wavelength that is close to the first but will be absorbed less by the vapor. These sets of wavelengths were determined by JPL during the research phase of this effort. The two laser beams are then combined into a single beam, which is expanded and transmitted to a target that will reflect the IR energy (asphalt, trees, etc.). The reflected beam received back is focused onto an HgCdTe detector, which produces an electrical signal that is amplified and processed by the electronics for display. The electronics determine the concentration of the vapor by sepa-

rating the received signal into the original laser signals and taking the ratio of the two signals, which gives a concentration-pathlength result.

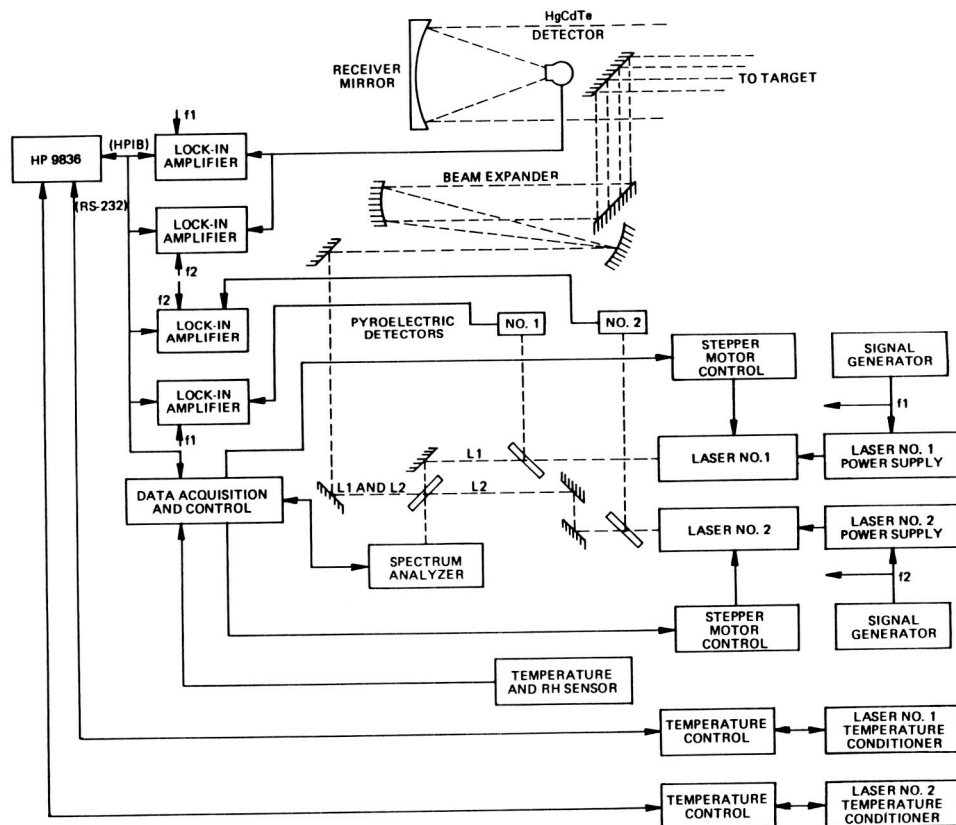
KSC has taken the basic elements of the JPL-delivered system and added an HP 9836 desktop computer and data acquisition and control hardware, shown in the figure "Instrument System for Remote Sensing of Hydrazine," which allows the system to operate under computer control as shown in the figure "Computer Controlled System." The computer will use predetermined settings or calculate values to set up and control the temperature controllers for the lasers, set up and control the lock-in amplifiers, and tune the lasers to the proper wavelengths for the vapor selected. The computer will read the output of the lock-in amplifiers and calculate the concentration-pathlength of the vapor detected, output the results to the CRT, and continuously update the CRT. Field testing is planned this year at NASA White Sands Test Facility. The testing will determine least detectable concentrations and least detectable spill volume for both hydrazine and monomethylhydrazine. Lessons



*Laser Remote Sensing System*



*Instrument System for Remote Sensing of Hydrazine*



*Computer Controlled System*

learned during this testing will enable design and fabrication of an operational prototype unit.

M.M. Scott, Jr., 867-3475  
William R. Helms, 867-4438

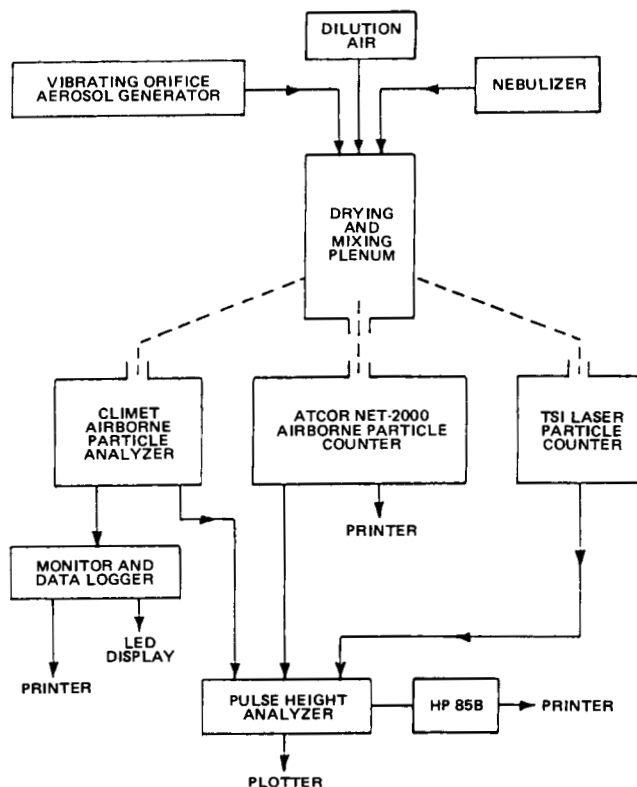
DL-ESS-32  
DL-ESS-31

## Minimizing Variability for Optical Particle Counters

**Objective:** To determine the source of variability in particle count between various particle counters and a means of decreasing this variability.

**Background:** Previous studies had shown that optical particle counters used for monitoring cleanroom environments exhibited significant variability in particle count, and that the degree of variability depended on sample tube diameter, sampling rate, and uniformity of standard particles used for size calibration of the various instruments. More extensive, detailed studies have now been carried out in order to assess the relative importance of these three influencing factors and to determine the minimal level of variability achievable.

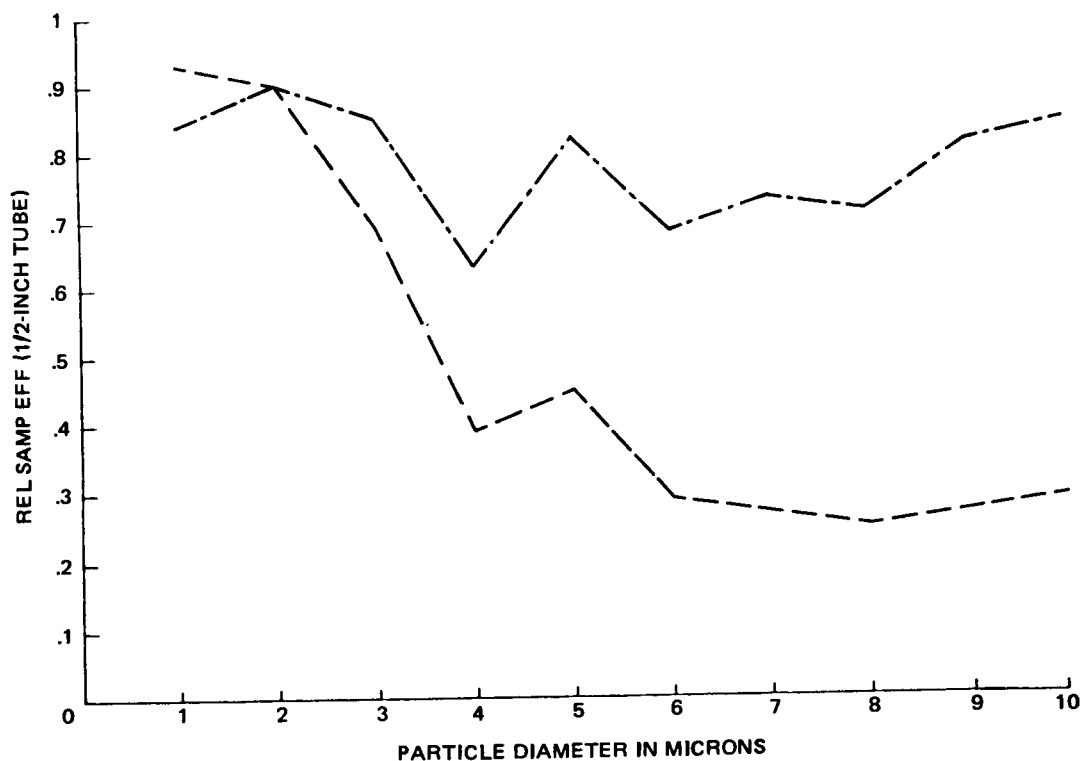
**Approach:** Extensive, comparative studies involving the Climet CI-226 Particle Analyzer and the TSI Model 3755 Laser Particle Counter were carried out, with somewhat more limited studies being done with an Atcor particle sensor. The Climet counter is a white-light based instrument, while the other two contain a laser diode for the radiation source. The basic experimental configuration is outlined in the figure "Experimental Setup." Test aerosols in the 0.5- to 5.0-micron range were generated using either a vibrating orifice device or a compressed air nebulizer. The former produces liquid oil droplets; the latter solid styrene spheres. Particle counting was accomplished by analyzing raw pulse signals directly with a pulse height analyzer. Sample tube diameter effects were studied by comparing sampling efficiency of an optical counter at a set flow rate for varying tube diameters. Correlation studies were carried out using mono-disperse polystyrene latex aerosols of 0.5-, 3.1-, and 5.0-micron volumetric counts as recorded by the Climet and the TSI units. Each unit was operating at its natural sampling rate. Additional experiments aimed at determining the standard calibration curve for the TSI sensor and evaluating the relative performance of the Atcor particle sensor were performed.



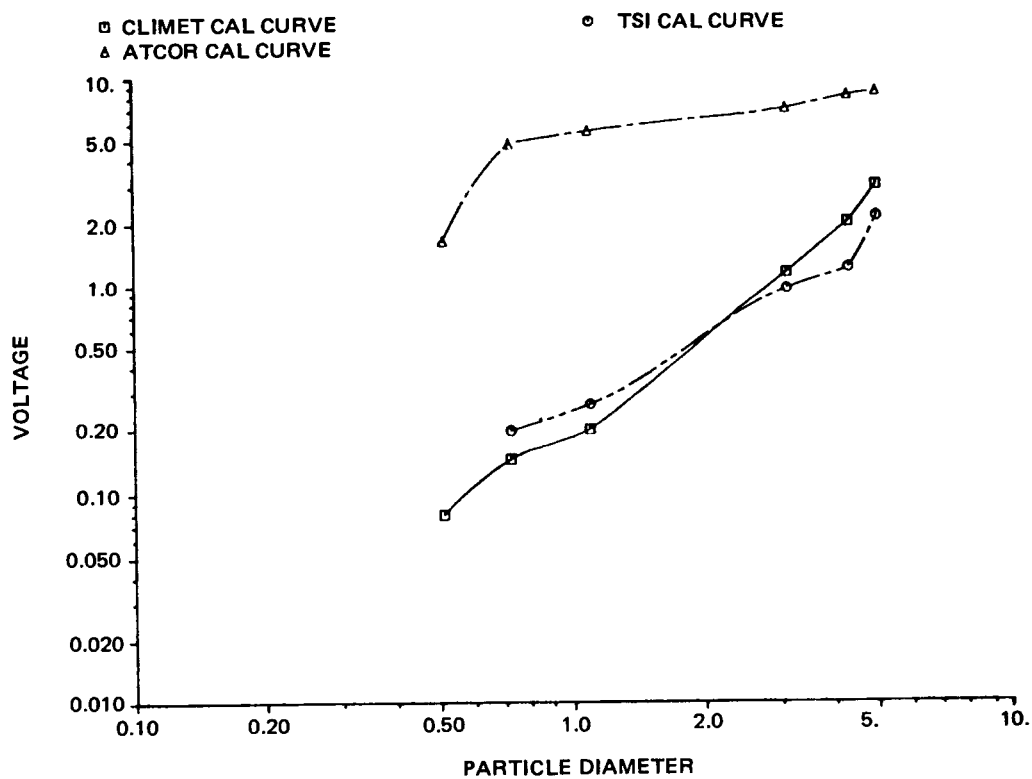
*Experimental Setup*

**Summary of Results:** The results indicated that 1) sample tube diameter and flow rate do affect sampling efficiency for liquid particles, with counting efficiency decreasing with decreasing tube diameter and increasing particle size, 2) by standardizing particle size, i.e., using identical particles for calibration, variability in counting model test particles can be essentially eliminated, 3) the particle size-signal voltage calibration curve of the TSI laser diode-based instrument may exhibit a resonant "kink" at or near 5.0 microns. The Atcor sensor compares favorably with the other two units in signal/noise, counting efficiency, and size resolving power near 0.5 microns where counting efficiency is less than 10% of the counting efficiency of the other two. In regard to 2) above, the count correlation for the Climet and TSI units at three particle sizes was better than 95%, illustrating that for solid particulates the uniformity of the calibration particles is the primary determinant of instrument variability for model aerosols.

J. C. Travis and William R. Helms, 867-4438  
DL-ESS-31



*Particle Size vs Voltage Output Comparison*



*Effect of Tube Diameter  
3/8- and 1/4-Inch Tubes*

## Bolt Gage Development

An ultrasonic extensometer ("bolt gage") is used for measuring preload tension in the eight SRB holddown bolts at KSC (see the figure "Holddown Post Showing Top of Holddown Bolt"). Although the ultrasonic method is very accurate, the instruments used are basically laboratory instruments in a field environment. The system is shown in the figure "Bolt Gage System." Additionally, the bolts are made of high-tensile alloy and are often subjected to bending moments in the tensioning operation. These factors can cause false readings by the extensometer, and require a skilled operator for interpreting the results. An effort to improve the reliability of the bolt gage is under way including:

1. Modification of the holddown bolts for the use of glued-on, disposable transducers. This will allow test

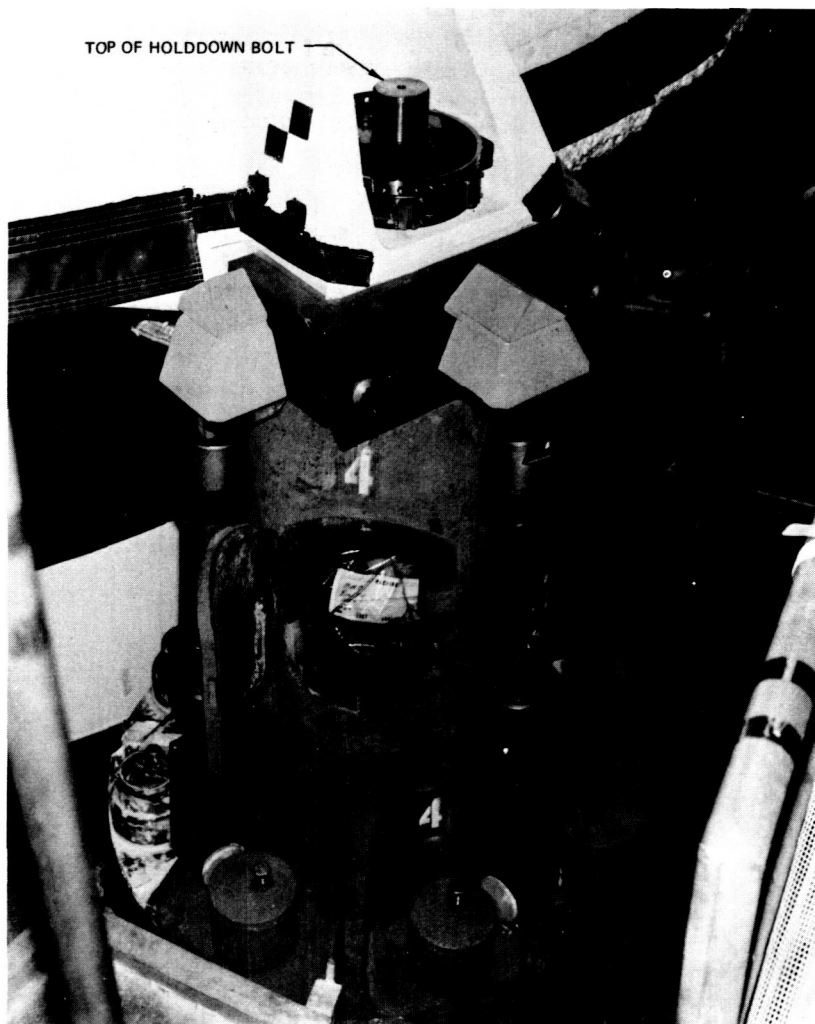
of the transducer coupling and ultrasonic waveform prior to the actual installation of flight hardware at the MLP.

2. Modification of the pulse-transmitting circuitry of the bolt gage to improve the received pulse waveform (if we can obtain a one-pulse echo, this will certainly get rid of problems with "peak-jumping").

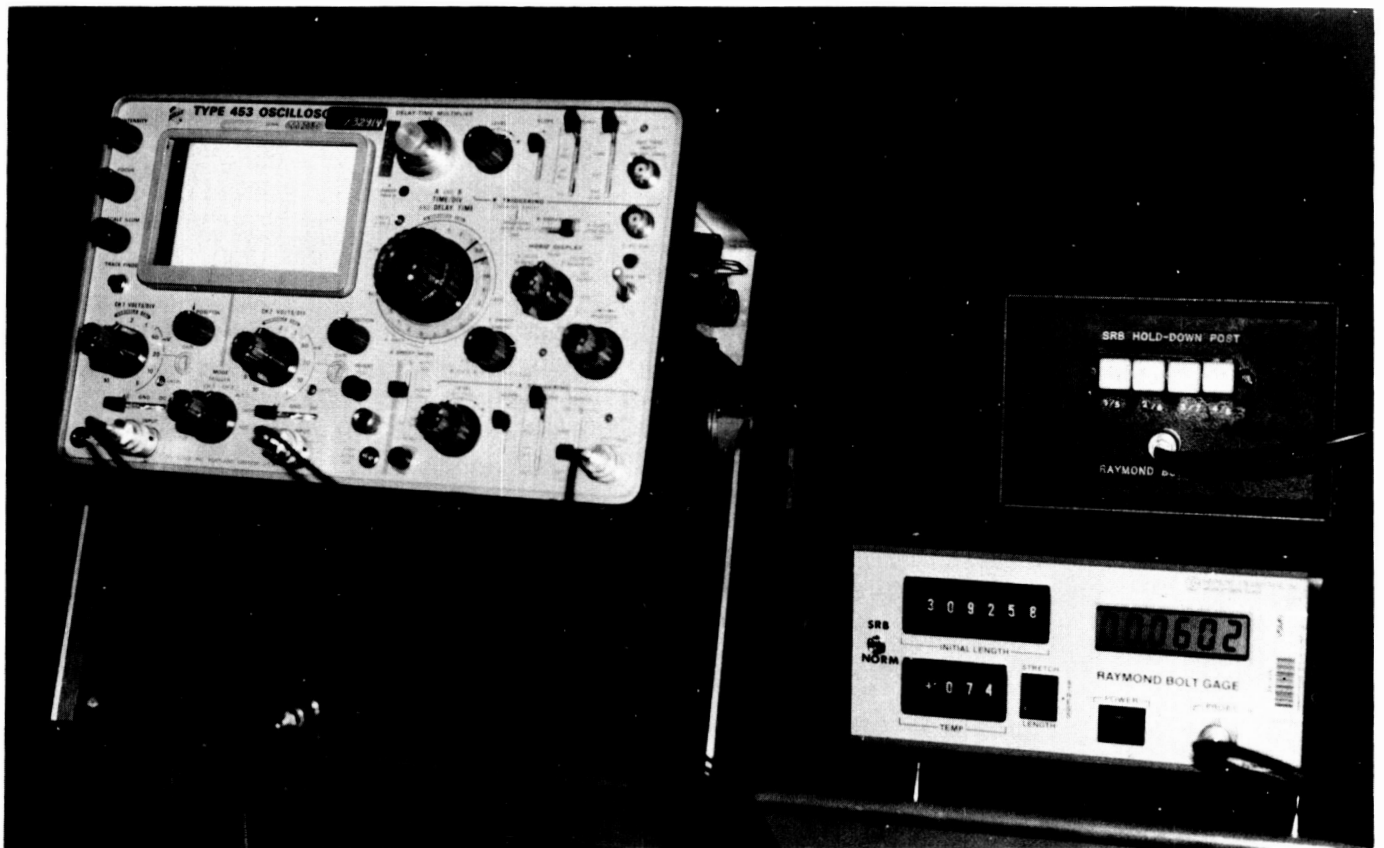
3. Use of a recording bolt gage, which gives a strip-chart output of bolt stretch versus time. If peak-jumping occurs, it will be evident; and the correction required will just be the step on the wave-form. This will obviate the need for an oscilloscope to be used in conjunction with the bolt gage.

J. David Collins, 867-4438  
Chuck Griffin, 867-4438  
William R. Helms, 867-4438

DL-ESS-31  
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DL-ESS-31



*SRB Post Showing Top of Holddown Bolt*



*Bolt Gage System*

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## **Evaluation of the Effect of Various Abrasive Blasting Grits on Paint Performance**

Silica sand is currently the most common abrasive blasting media used for surface preparation of carbon steel in coating operations. However, because of concerns of OSHA and EPA over the possibility of silicosis associated with its use, restrictions are anticipated in the future that will increase the demand for other abrasive blasting materials. For this reason, a study was conducted to evaluate other blasting grits as potential substitutes for the silica sand.

Nine abrasive grits were studied in this program for their effect on coating performance. Before blasting, 4- by 6-in carbon steel panels were placed at the KSC beach corrosion site for one week to provide a uniform, rusted surface and to provide time for salt to deposit on the surfaces. After being removed from the beach, ten panels were blasted with each of the nine grits. Half of the panels were water blasted before grit blasting and half were grit blasted only. Bare blasted carbon steel panels were examined for imbedded salt and grit blast particles and a profile analysis was performed. Painted panels were subjected to environmental exposure tests including salt-fog chamber tests (for accelerated corrosion) and beach corrosion site tests (for normal exposure). The advantages and disadvantages of each of the abrasive grits were evaluated and the best of the nine materials was determined.

Results of this study showed that surface preparation does play a role in the coating performance. In general, the larger the grit, the larger the profile on the metal. The larger profiles were harder to cover with paint; thus, spots of rust formed quickly. In all cases, a significant amount of grit material, ranging from about 8% to 25%, was found imbedded in the surface area following the blasting operation. The chemical content and the size of the particles may have also played a role in the coating failure. Salt was not found imbedded or present on any of the panels; water blasted or non water blasted. In this study, water blasting before grit blasting did not play a major role in the paint effectiveness.

This program is the beginning of a larger-scale research program to be started in the near future to include more materials and more testing. The extended program will include a further in-depth study as to the effect of imbedded particles and salt contamination on carbon steel coatings. The study and evaluation time period will be longer than the three months used in this preliminary program.

Melodie M. Porta, 867-4344

DM-MSL-2

## **Evaluation of Shuttle Tile Bonding Problems Experienced With 0.090-inch SIP and RTV 560**

As a result of bonding problems noted when removing thermal protection system (TPS) tiles from the Orbiter, a study was initiated to examine these bonding problems and their causes. These problems included poor adhesion between the 560 RTV and the substrate, lack of strain isolator pad (SIP) fiber penetration into the RTV layer, and the effects of moisture condensing conditions on the bonding surfaces during tile operations.

Over 600 sample bonds were prepared during the study. Numerous variables in the bonding process were explored to obtain insight into factors that led to the types of bond failures noted during refurbishment and repair operations at the Kennedy Space Center. The factors examined included the relationship between cure pressure and working life, Koropon epoxy aluminum primer cure time, effects of contaminants, preparation and application techniques, temperature and humidity effects, etc. Further testing focused specifically on the RTV primer. Environmental and other tests were performed to gain an understanding of the factors influencing successful priming of the substrate before application of the RTV 560 adhesive film. The curing and priming properties of the General Electric (GE) 4155 primer were characterized in a series of environmental tests over a range of temperature and available water vapor conditions. Although these tests helped to identify environmental influences



on the priming process, there are still numerous questions to be answered. There are continuing indications that the primer can exhibit erratic behavior that results in inadequate priming of the substrate after application per accepted procedures and conditions.

N. P. Salvail, 867-4614

DM-MSL-2

## Metals Ignition in High Pressure Oxygen

During the past several years, the White Sands Test Facility (WSTF) of the Johnson Space Center has developed three methods to evaluate the flammability and ignition properties of metals in pressurized oxygen. WSTF is now evaluating the metals used in existing Kennedy Space Center oxygen systems in support of Space Shuttle operations and several metals being considered for new systems.

The three test methods developed by WSTF are: rubbing friction, particle impact, and promoted ignition. The metals being evaluated include several stainless steels, a carbon steel typically used in vacuum storage vessels, nickel, and several nickel/copper alloys.

The particle impact tests were conducted using sand, rust, and iron particles. Ignitions were obtained only with the iron particles, which suggests that the ignition of the particles themselves plays an important role in the ignition of metals. In these tests, the particle size was kept constant and the oxygen pressure and velocity were the variables.

The promoted ignition tests have also been completed. The nickel/copper alloys were the most resistant to ignition and burning while the iron-based alloys easily ignited and burned.

Rubbing friction tests are scheduled to be completed in the coming year.

C. J. Bryan, 867-4344

DM-MSL-2

## Permeability of Polymers to Organic Liquid and Condensable Gases

Workers involved in the production, use, and transportation of hazardous chemicals can be exposed to numerous chemicals capable of causing harm to the human body. The effects of these chemicals can range from acute trauma such as skin irritation and burns to chronic degenerative disease such as cancer or emphysema. Since engineering and administrative controls may not eliminate all possible exposure, attention must be given to reducing the potential for direct contact through the use of polymeric-based protective clothing that resists permeation, penetration, and degradation.

Permeation tests are being performed by the Tuskegee Institute to evaluate the protection afforded by various materials used in the fabrication of protective clothing. This evaluation determines the breakthrough time and the steady-state permeation rate for particular chemical/clothing combinations. Materials of interest are butyl rubber, Neoprene, poly(vinyl alcohol), poly(vinyl chloride), latex rubber, and chlorobutyl rubber coated Nomex fabric. Chemicals of interest include nitrogen tetroxide, hydrazine, monomethylhydrazine, hexane, toluene, and dimethylformamide. After the initial permeation tests are performed using the standard ASTM F-739 cells, the materials may be decontaminated and the resistance to permeation again determined to determine the effect of repeated chemical exposure on the protective clothing.

C. J. Bryan, 867-4344

DM-MSL-2

## Conductive Organic Polymers as Corrosion Control Coatings

For the past twenty years, inorganic zinc-rich coatings have been used to protect the launch structures at the Kennedy Space Center (KSC). However, the launch of the Space Shuttle releases large quantities of hydrochloric acid that subsequently attacks the zinc portion of the protective coating systems and the steel launch structures soon begin to corrode. This attack necessitates frequent and expensive repair

procedures that may interfere with launch critical operations. The electrically conductive nature of these zinc-rich coatings suggested the use of electrically conducting organic polymers as protective coatings. These organic coatings should be resistant to hydrochloric acid, easy to apply, maintain and repair, and provide long-term resistance to the KSC environment. Three basic polymer systems are being studied: polyaniline, at the University of Pennsylvania, and polypyrrolone and Polyphenylquinoxaline, at the Los Alamos National Laboratory (LANL).

Solutions of polyaniline have been prepared that permit brush or dip coatings to be applied to iron, steel, and stainless steel. Good protection of stainless steel in highly acidic salt solutions has been obtained with this polymer system.

Work on the development of high-temperature organic coatings for brush and dip application is underway at LANL. Studies on accelerated corrosion test procedures are also under review.

Studies will continue to focus upon formulation, application, and evaluation. The first coatings to be tested by exposure to the KSC environment should be ready for testing this year.

C. J. Bryan, 867-4344

DM-MSL-2

## Protective Coating Systems For the STS Launch Environment

Zinc-rich coating systems for exposure to the STS launch environment have been suffering premature failure due to the highly acidic residue produced by the Solid Rocket Boosters. Early attempts at top-coating these zinc-rich coatings with thin film topcoats to increase their chemical resistance have produced only marginal results.

Currently, other topcoat systems are being tested to improve coating performance for exposure to this harsh environment. The present study focuses on using thicker film topcoats over the zinc-rich primers to improve the chemical resistance to both a marine atmosphere and the highly acidic residues.

Presently, some 119 materials producing 67 coat-

ing systems are being exposed to atmospheric contaminants at the KSC beach corrosion site with concurrent application of an acid slurry made of hydrochloric acid and alumina ( $\text{Al}_2\text{O}_3$ ). The slurry is applied to the KTA (Tator) panels with no subsequent wash-down to simulate the worst-case scenario experienced at the launch sites.

The current test will be conducted for 5 years to determine the suitability of the topcoat systems. The panels will be judged for performance at 6, 12, 18, 36, and 60 months. During this 5-year period, there will be approximately 130 applications of the acid slurry.

The panels are currently approaching the 18-month point and results of this evaluation will be published in the near future.

L. G. MacDowell, 867-2906

DM-MSL-2

## Study of Thermal Sprayed Metallic Coatings For Potential Application on LC-39 Structures

The objective of this study is to evaluate candidate thermal sprayed metallic coatings for potential application on the Zone 1 structures at LC-39. Tests are being performed to determine if the candidate coatings will protect the structure from the abrasive blast, heat, and acid-rich environment associated with the Solid Rocket Booster (SRB) exhaust during Shuttle launches.

Launch Complex 17 (LC-17) was selected for the first series because, at the time, it was the only active launch site that utilized solid rocket motors (SRM's) on the launch vehicle. The Delta launch vehicle utilizes 9 SRM's, 6 of which are ignited at lift-off.

The initial results were not encouraging. The coatings experienced cracking and debonding from the substrate due to thermal shock. Additional test panels are being coated, with improved adhesion/bonding a primary concern, and tests on the Titan III Pad, Launch complex 40, are planned.

Peter J. Welch, 867-4614

DM-MSL-2

## Nonvolatile Residue Measuring System Development

Hardware and systems associated with space flight demand stringent cleanliness requirements. In addition to particle counts, nonvolatile residue (NVR) is a critical portion of the cleanliness requirement. NVR is normally thought of as the thin, oily film often found on parts and components.

In the traditional method of measuring NVR, a component is rinsed with clean solvent. The resulting contaminated solvent is collected; the solvent sample is evaporated; and the remaining residue, NVR, is weighed.

Evaporation of the solvent sample is a time consuming operation which slows the entire cleaning process. The evaporation can be accelerated by either heating and/or lowering the atmospheric pressure of the sample. However, both of these techniques may result in loss of a portion or all of the NVR, because portions of the NVR become volatile as the temperature increases and the pressure decreases.

NASA personnel surveyed the manufacturers of particle counters, reflectometers, etc. to determine if there were any devices on the market suitable for the NVR application. None of the vendors appeared to have the capability required. However, the inquiries raised the interest of at least one company, which had apparently done a market survey and found that there is a potential market for a "Solvent Purity Meter." They

have been working with NASA to perfect the device, which may meet the NVR requirements.

Peter J. Welch, 867-4614

DM-MSL-2

## Corrosion of Convolute Metal Flex Hoses

Various cryogenic supply lines and hypergol fuel lines at the Shuttle launch site use convoluted flexible hoses and bellows constructed of 304L stainless steel. The extremely corrosive STS launch environment composed of sodium chloride and HCl has caused rapid pitting and failure of these flex hoses. This leads to loss of vacuum with resulting high boil-off of the cryogenics.

Currently, 19 corrosion-resistant alloys are being tested for pitting resistance. The present study focuses on nickel-based alloys and more resistant stainless steels. These alloys were chosen on the basis of their reported resistance to acid/chloride environments.

Many different corrosion tests are being conducted to screen the alloys for pitting and corrosion resistance. These include linear polarization, cyclic polarization, ferric chloride immersion, salt fog/acid slurry exposure, beach exposure, and stress corrosion cracking tests.

L. G. MacDowell, 867-2906

DM-MSL-2

# ROBOTICS

## Robotics Applications for Remote Umbilicals

At KSC, the Space Shuttle Vehicle (SSV) requires umbilical connections for fuel; communications; heating, ventilating, and air conditioning (HVAC); hydraulic power; electrical power, etc. Most of the connections are hazardous to worker safety (mainly the hypergolics and cryogenics), repetitive and heavy/cumbersome to handle. The largest umbilical, the Tail Service Mast (TSM), weighs approximately 1,500 lb.

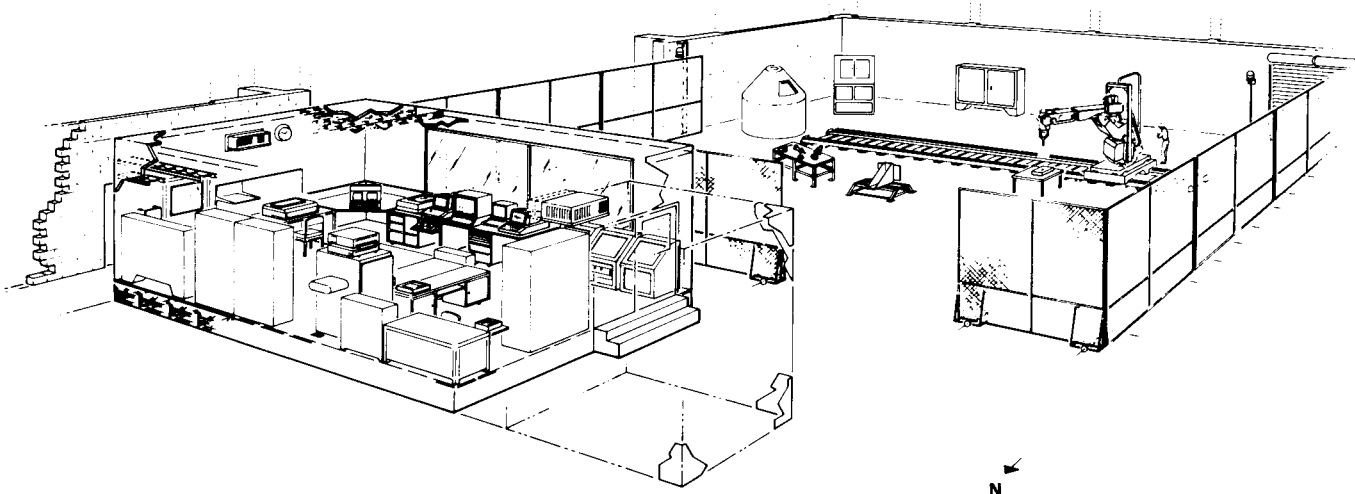
NASA/KSC is currently working on the system definition and hardware requirements utilizing robotics in support of an automated soft connect/disconnect function for the T-O (lift-off) umbilicals.

For the final 300 seconds before launch of an SSV, all systems are retracted except for the T-O umbilicals. They are connected until the time of launch because manual reconnect currently takes technicians 24 to 32 hours, and an aborted launch attempt would require that LOX and LH2 be off-loaded promptly. NASA/KSC is currently working on a robotic automated umbilical system for future T-O umbilicals that would allow a soft disconnect at several minutes before projected

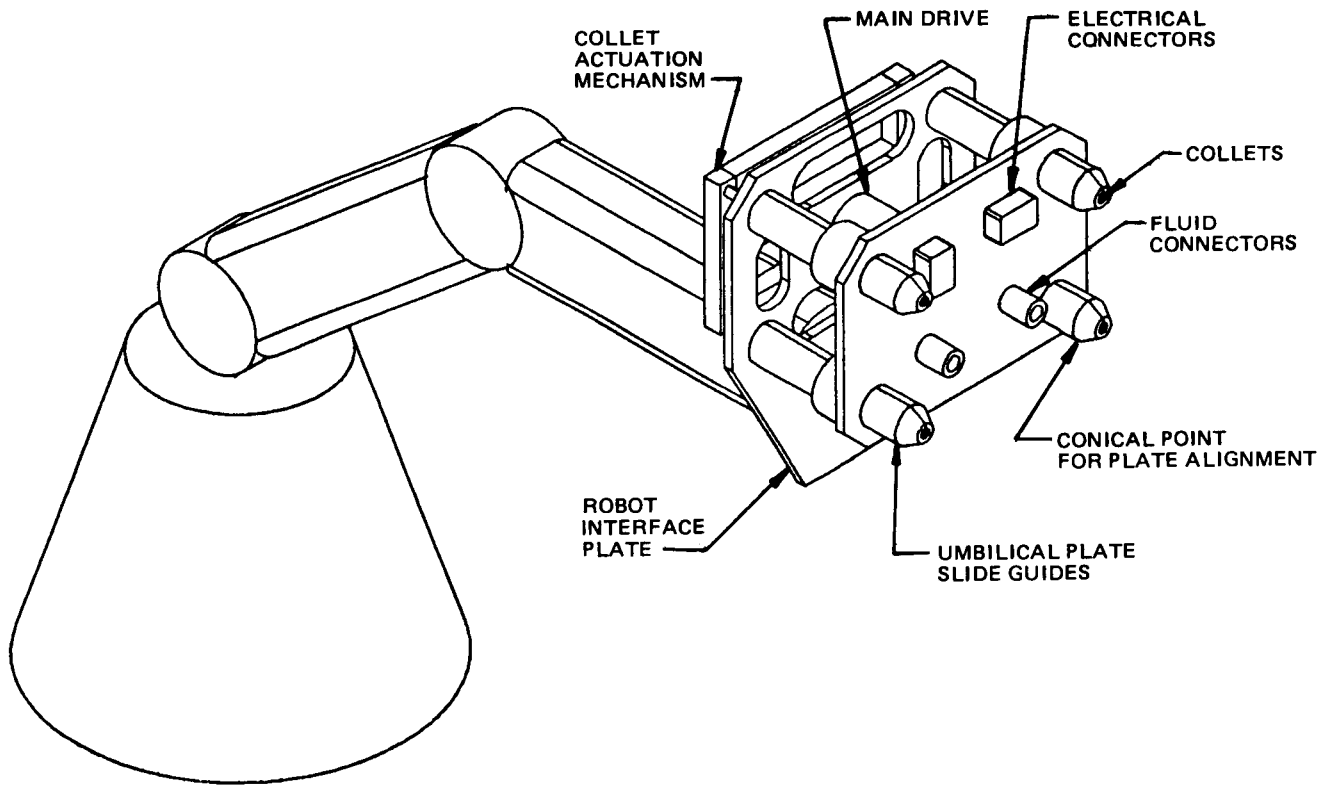
launch time, with the capability to reconnect promptly in case of delay. NASA's Robotics Applications Development Laboratory (RADL) is researching special quick disconnects, electrical connectors, and umbilical plates to perform this operation. One result from this research is the Generic Remote Umbilical Plate which is currently in the design phase.

Additionally, several mating techniques are under investigation using a combination of active/passive compliance and vision technologies. Machine vision will position the robot in a coarse manner while active compliance through the use of force feed-back will complete the mating process.

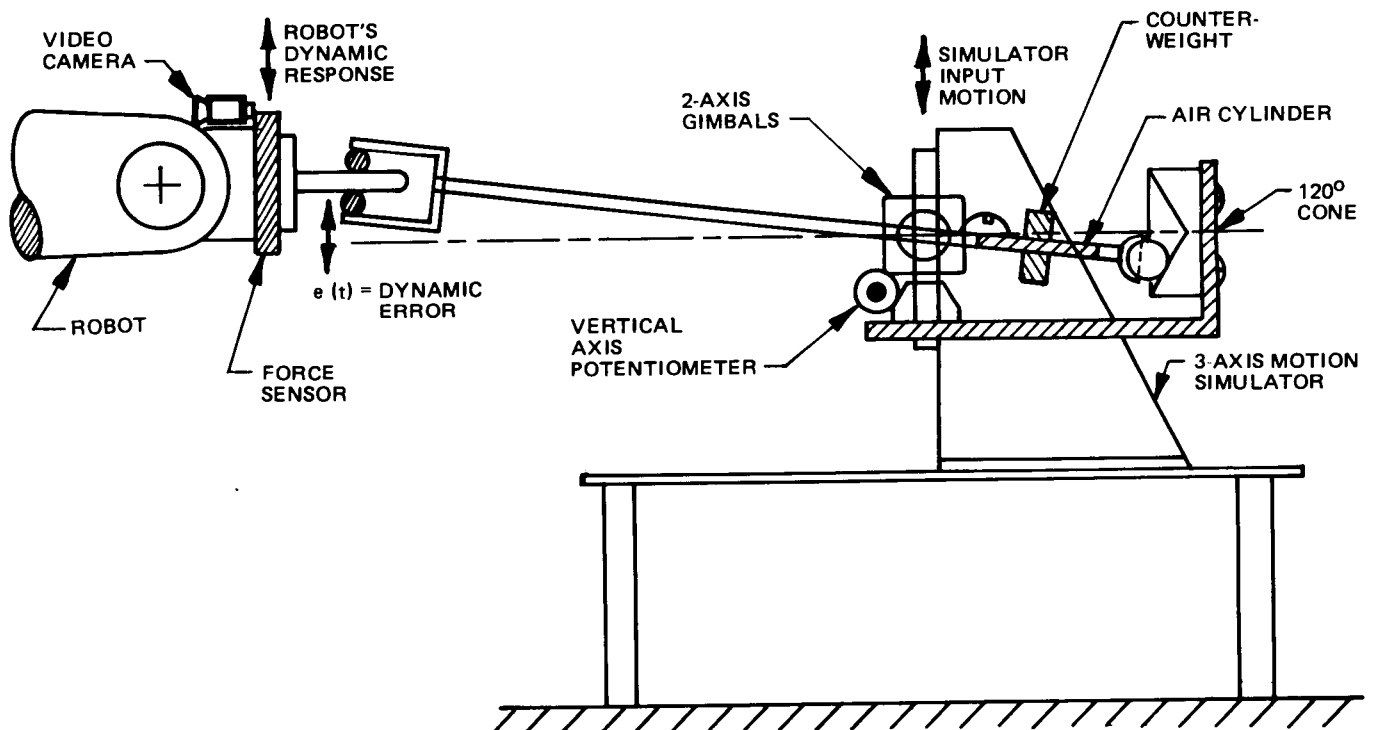
The RADL's Force Feedback Test Fixture (FFTF) was developed to further test these mating concepts. The main purpose of the FFTF is to quantitatively measure the dynamic response of the robot's operating spectrum. To simulate the affect of wind excitation on the SSV, the fixture is driven along the X- and Y-axes of a 3-axis simulator. A constant force is applied to the robot's end-effector which is measured by the force sensor and relayed to the robot control system. The fixture's probe arm consists of a 2-axis gimbal mounted to the simulator plate, with potentiometers along each axis to detect tracking errors between the



*Robotics Applications Development Laboratory (RADL)*

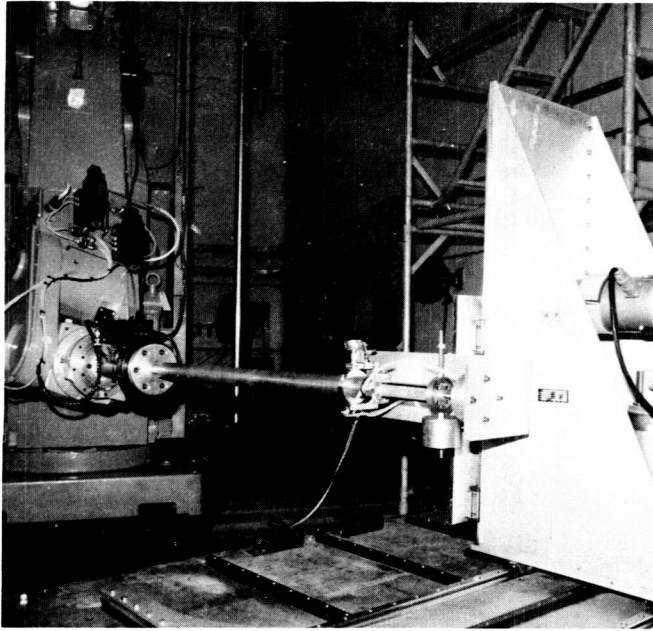


*Generic Remote Umbilical Mounted on Robot*



*Force Feedback Test Fixture (FFTF)*

simulator's motion and the robot's corresponding tracking response.



*Robot Docking With FFTF*

To complement these efforts, analytical models are currently in the development stage to study the performance of various passive compliant end effectors under conditions similar to KSC applications. Results from these models will indicate the magnitude of the position/orientation inaccuracies and forces once the compliant device is mated.

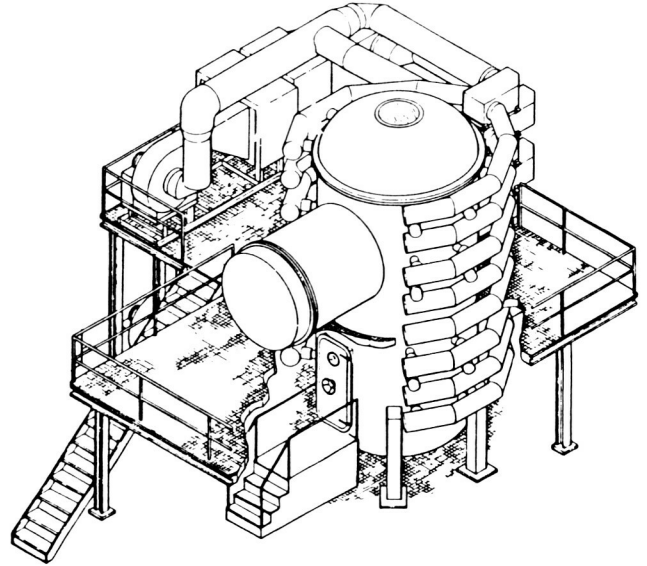
V. Davis, 867-4181

DM-MED-12

## **Robotic Automation in the Controlled Ecological Life Support System (CELSS)**

The goal of the CELSS is to integrate elements of a biological regenerative life support system within a large (24- by 12-ft) atmospherically sealed plant

growth chamber, known as the Biomass Production Chamber (BPC). The performance of methods and equipment is tested by the CELSS for use in sustaining humans during long-duration spaceflight.



*Biomass Production Chamber*

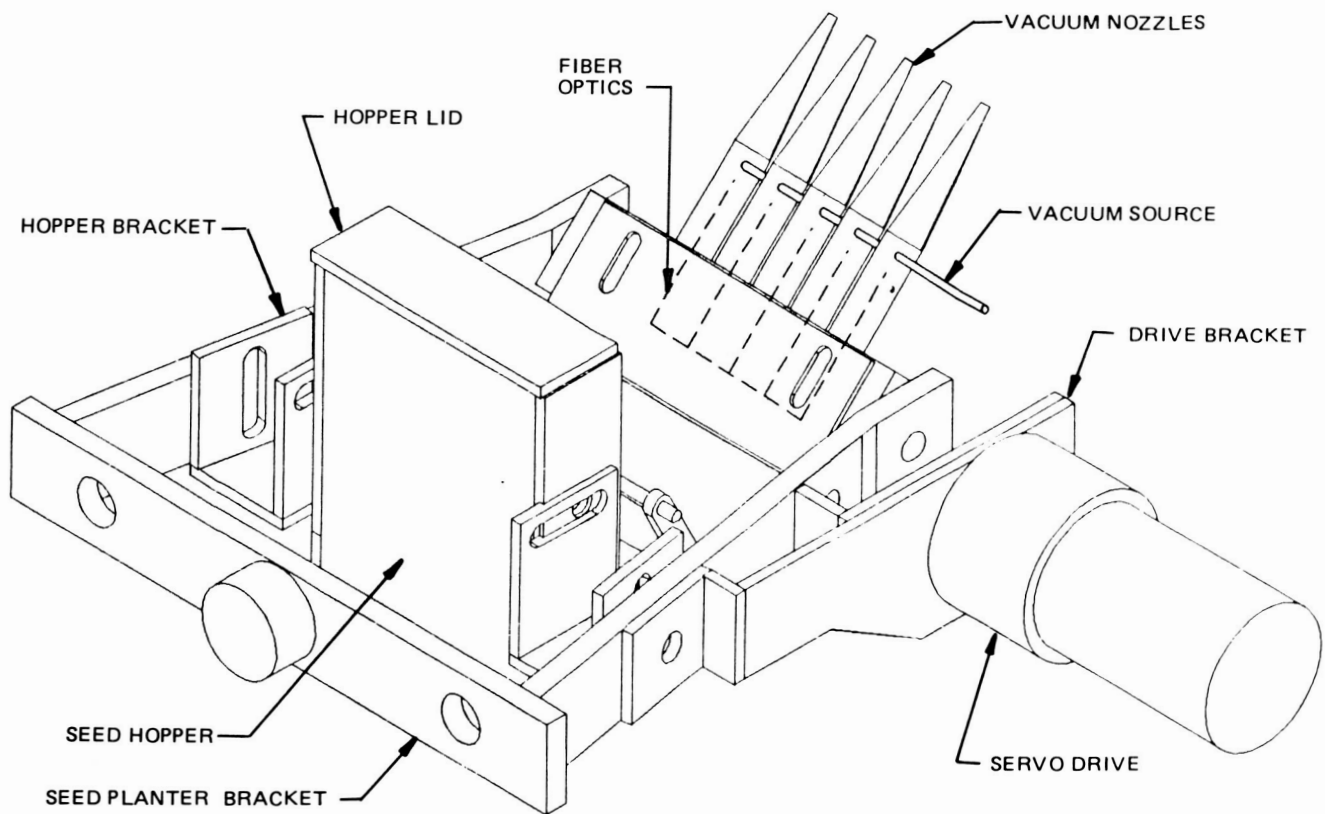
Current plans are to use robotics to automate the manually intensive tasks of planting, cultivating, and harvesting crops in the BPC. A prototype seed-planting end effector is presently under construction to automate the sowing of wheat seeds in hydroponic collection trays. A typical planting operation includes the five nozzles, attached to a vacuum source, accessing seeds from the hopper. The nozzles rotate from the hopper and are checked by optoelectronics for seed presence. Once the nozzles are perpendicular to the hydroponic tray, the seeds are released into their respective germination locations.

Cultivation tasks will consist of rotating the trays within the BPC and collecting plant samples for off-line analysis. Crop removal and processing will take place during harvesting operations. Each of these tasks are presently in the investigation stage.

E. Lopez del Castillo, 867-4181

DM-MED-12

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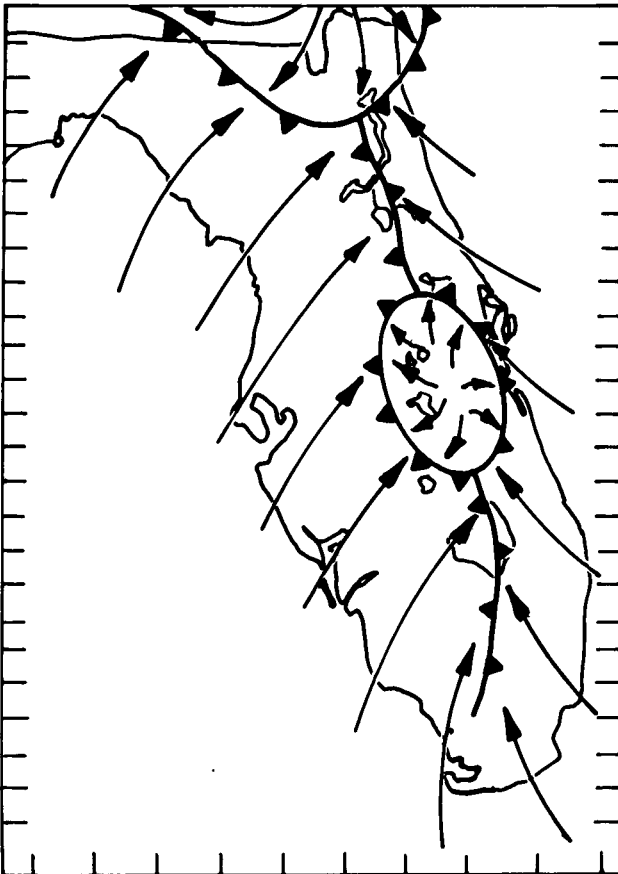
*Seed Planting End-Effector*



*Three Hydroponic Growing Trays With Young Wheat Plants*

## Numerical Weather Modeling

Reliable thunderstorm forecasting is required for KSC operations and for Shuttle launch and landing at KSC. However, summertime thunderstorms at KSC are very hard to predict because they are usually caused by "seabreeze" circulations. These circulations occur because of the difference in temperature between land and the sea. Florida is basically a peninsula, so there are two seabreeze circulations, one develops on the west side and moves east; one devel-



**NOTE:** At least two large thunderstorm mesohighs were in evidence over the Florida Peninsula along with the confluence line of the southwesterly and southeasterly sea breezes meeting over mid-peninsula.

*Mesoanalysis of Surface Winds, 2300z, 5 May 1984*

ops on the east side and moves west. They can trigger thunderstorms by themselves, and where they collide (Seabreeze Convergence Zone), thunderstorms often develop. After the Seabreeze Convergence Zone develops, it often moves east. Whether thunderstorms develop, however, is not a certainty. It depends on the moisture available in the atmosphere, upper-air winds, and many other factors. Clearly, reliable summer thunderstorm forecasting presents a significant technical challenge.

R\*SCAN Corporation and ASTER Corporation, under contract to NASA, have been developing and testing a computer model that determines whether a seabreeze circulation will develop, if thunderstorms will result, and when, if at all, the thunderstorms will affect KSC. The computer model, called the P2DM/P3DM, works only in the summertime at KSC. A field test using the P2DM model has been in progress for two years. Nearly 83 case days of data have been collected. This year, the model output data and an interpretation were provided to forecasters for evaluation. In addition, R\*SCAN has conducted a blind test of the computer model, to determine whether a forecaster, using the model, will really do a better job. Preliminary results suggest the model could significantly improve the forecasters' summertime forecasting skill.

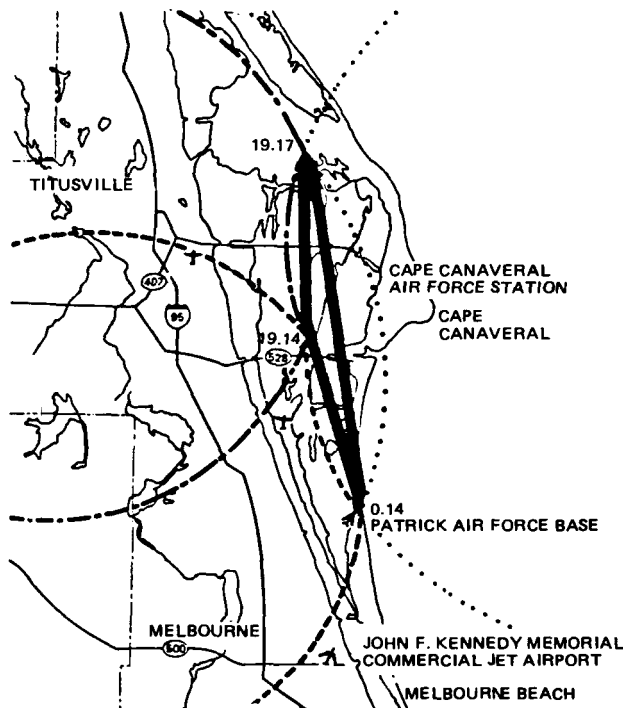
R. Wesenberg, 867-4438

DL-ESS-31

## Clear Air-Wind Sensing Doppler Radar (CADR)

A reliable, 90-minute thunderstorm forecasting capability is essential if the Space Shuttle is to land at Kennedy Space Center (KSC). Discussions at KSC meteorology workshops with many weather research people suggests that clear-air wind-sensing using a doppler radar may provide such capability. Recent research at other national laboratories substantiates this suggestion. This project has been planned to move CADR from the forefront of research to an operational system at KSC as quickly as possible to meet KSC's needs.





RADARS 19.17; 0.14 · · · · ·  
 RADARS 19.17; 19.14 - - - - -  
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 NOTE: SOLID LINES DESIGNATE BASELINES

### Dual Doppler Radar Coverage Area

During this past summer, KSC and Air Force Geophysical Laboratory jointly field tested a clear-air wind-sensing radar at KSC (see Pulse C-Band Radar Detection of Clear Air Phenomena) and CADR Work Station software was developed.

The concept was to develop an integrated CADR Work Station software package that would allow technique development on small, inexpensive, 80386/68020-class PC's or VAX-class minicomputer. ADA language was used for the software, and the graphics standard was GKS to stress portability. Object-oriented design was used for the analytic techniques, to stress the correctness of the software implementation. The result is a system that integrates four basic, single-doppler, clear-air, wind-sensing analysis techniques; Volume Velocity Processing (VVP), Modified Volume Velocity Processing (MVVP), Box Velocity Processing (BVP), and Convergence Line Velocity

Processing (CLVP), a new technique developed at KSC. A two pass de-aliasing system has been developed. A utility to convert data tapes from a local format to the Universal Doppler Data Format has been developed. An interim display system has been developed, and an integrated display and data base is under development. The software has been tested and verified on both a VAX 11/780 and a Compaq 386 computer.

During this coming fall and winter, the data collected by the field test will be converted to Universal Format, and the integrated analysis software will be completed. The data and work station system will be made available to meteorologists and researchers for development of new analysis techniques and forecasting methods. The work station will become the basis for forecasting evaluations to determine the improvements in forecasting skill that can be achieved using a CADR.

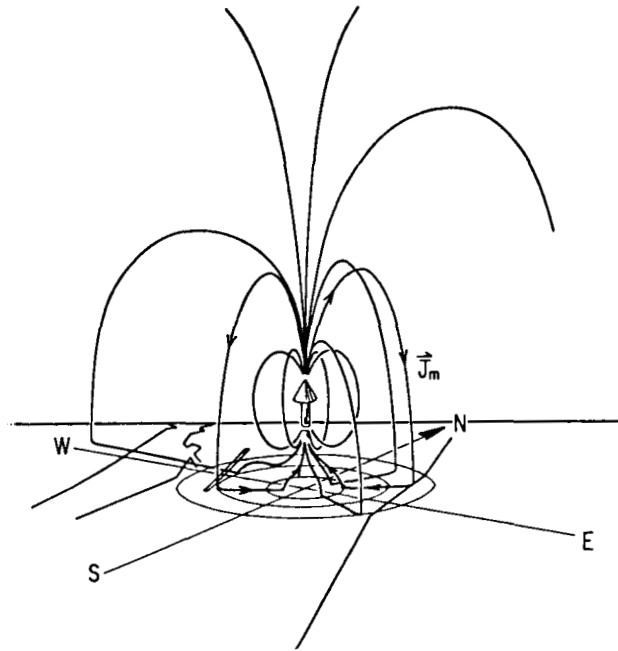
R. Wesenberg, 867-4438

DL-ESS-31

## Thunderstorm Currents

Lightning can make the handling of propellant and ordnance materials at KSC a very hazardous occupation. A system that detects the potential for lightning is in operation at KSC; however, the system cannot predict whether the lightning hazard is increasing or decreasing. To do that, the state of the thunderstorm generator itself must be determined.

Some recent developments suggest that this may be possible. Recent research in atmospheric electricity conducted by the University of Arizona Institute of Atmospheric Physics suggests that an electric-current sensor network may be able to track the state of the thunderstorm generator that produces the electricity that results in lightning. In the figure below, the large arrow in the center represents the thunderstorm generator, while the contours represent current density streamlines. Since charge is conserved, the streamlines make closed loops. The fact suggests that, from an array of current sensors located on the ground, the state of the thunderstorm generator might be determined. This simplified picture may be complicated by many factors; the best way to determine whether ground-based current sensors can characterize the thunderstorm current generator is by a field experiment.



*Theoretical Description of Typical Thunderstorm Generator's Structure in terms of Current Density ( $J_m$ )*

During this past year, researchers have completed further experiments on Maxwell current sensors and have been completing analysis on the data. This year, an independent review will be made by a committee of scientists, to determine whether any development,

design and implementation should begin. If the review is favorable, the effort to develop the system will begin.

R. Wesenberg, 867-4438

DL-ESS-31

# ARTIFICIAL INTELLIGENCE

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## Expert Mission Planning and Replanning Scheduling System

The Expert Mission Planning and Replanning Scheduling System (EMPRESS) is an expert system created to assist payload mission planners at the Kennedy Space Center (KSC) in the long-range planning and scheduling of scientific payloads for Space Shuttle flights. Using the current flight manifest, these planners develop mission and payload schedules detailing all processing to be performed in the Operations and Checkout (O&C) building at KSC. The EMPRESS system generates these schedules using standard flows that represent generic carrier processing timelines. Resources are tracked and resource conflicts are determined and resolved interactively. Constraint relationships between tasks are also maintained and can be enforced when a task is moved or rescheduled. The EMPRESS prototype, developed jointly by NASA and The MITRE Corporation of Bedford, Massachusetts, became operational in March 1986. A new version of EMPRESS, currently under development, will correct many of the limitations of the original prototype and enable EMPRESS to work with the ARTEMIS scheduling system.

As the primary launch site of the Space Transportation System, KSC is responsible for the final checkout, preparation, and installation of payloads into the Space Shuttle Orbiter. Processing of a horizontal payload occurs, primarily, at the O&C building in the KSC industrial area. This processing includes the tasks needed to assemble and install experiments onto a Spacelab carrier, as well as, the steps needed to perform experiment and subsystem functional verification prior to installation into the Orbiter.

To monitor and control this processing activity, NASA generates and maintains a hierarchy of schedules. At the top of the hierarchy is the flight manifest, which assigns launch dates, orbiter vehicles, and payloads to STS missions. KSC uses the manifest to generate long-range plans and schedules which detail support for the launch date milestones.

One such long-range plan is the Multiflow Assessment. This document contains Gantt charts that illus-

trate the major processing activities needed for each payload listed in the manifest. The Multiflow Assessment also contains information on the critical resource needs of these payloads. This enables early recognition of potential conflicts between limited resources. Because of the dynamic nature of Shuttle operations, payload mission planners are often required to develop new MFA's quickly when the manifest is changed, or to produce "what-if" schedules when examining unusual mission scenarios. EMPRESS is an effort to automate the process of producing the MFA and to respond quickly to changes in the launch manifest.

In a hypothetical EMPRESS session, the operator would first load a new flight manifest into the system. EMPRESS would then create a schedule for each horizontal payload on each mission. When creating a mission schedule, EMPRESS first determines if a schedule already exists. If not, EMPRESS creates a default schedule using a standard flow, which is a list of the tasks, task constraints, and resources required to process a particular horizontal carrier. When the default schedule is generated, the planner can then modify the tasks and resources as required. EMPRESS gives the planner the capability to verify that resource conflicts have not occurred between parallel operations and to revise resources and tasks automatically if conflicts exist. Constraint relationships between tasks are maintained and can be enforced when tasks are moved or rescheduled. The user interface is robust and gives the planner an excellent graphical representation of the schedule and detailed histograms of resource utilization. The operator may then save the schedule.

The domain knowledge base for EMPRESS is divided into three major areas; tasks, resources, and system heuristics. Task data include the various activities required to process a payload and parent-child or predecessor-successor relationships between tasks. Resource knowledge encompasses the people, hardware, and facilities required to process a payload. Resources are stored in a 1-to-n hierarchy. The heuristics in EMPRESS control the planning and scheduling. In addition, EMPRESS has a small forward chaining rule set used to resolve resource conflicts. These rules allow the operator to substitute an alternative

resource, to increase the workload of a resource, e.g., add more shifts, or to reschedule the task that caused the problem. The operator may choose to let EMPRESS resolve all resource conflicts automatically without operator input.

While EMPRESS provides an effective tool for payload mission planning, the prototype has limitations; primarily its lack of output. When a schedule is completed, the operator must use screen prints to obtain a hardcopy of the screen display. For lengthy schedules, this is bothersome and inefficient. In order to match the capabilities of the system currently in use, EMPRESS also needs to reproduce the format of MFA schedules.

Work has begun on the conversion of EMPRESS from a demonstration prototype to an operational system. This work will be performed jointly by NASA and the McDonnell Douglas Aerospace Corporation. This redevelopment effort will focus on improving the user interface and scheduler, on enhancing conflict resolution and justification capabilities, and on producing graphical output. The new EMPRESS will also access schedules from the commercial ARTEMIS scheduling system currently in use.

R. Pierce, 867-3526

CS-ISO

## Single Failure Point and Reliability Analyses

Single failure point analysis has been performed at NASA KSC for many years. It is currently performed manually by a team of engineers, a procedure which consumes many man-hours. The goal of the analysis is to identify each component in a system whose failure would cause the system as a whole to fail to meet its design goals. Using Artificial Intelligence techniques, a computer program called SFPA has been written which identifies the single failure points rapidly. Sufficient knowledge about the single failure point analysis process is embedded in the code to make the software "smart." Using a knowledge base which describes the hardware, the program performs the same analysis which is currently performed manually.

The algorithm is quite simple. A requirement, consisting of an item and a value for the item, is identified. This item may be a real component of the system or a state such as a pressure, temperature, etc. The first step is to create a list of the item's controlling objects, those objects upstream from the item whose behaviors directly affect the item. Each controlling object is routinely assumed to be failed, after which the requirement object is tested. If the requirement object can still attain the specified value, then the controlling object is not a single failure point. The controlling object is then "unfailed" and the algorithm proceeds to the next controlling object until the list of objects has been exhausted.

For the simple purge-pressure system used for demonstrations, the total time to perform the analysis is less than two minutes. The program was designed to run off-line, as an aid to the engineer during the design stage. However, it would also be possible to run the analysis real-time. As an example, if a failure occurred in a process, the analysis could be performed to inform operations of the new list of single failure points.

A reliability analysis is also packaged with the SFPA and is valid for series systems, two-line parallel systems, and combinations of both. The only additional data required are the mean-times-between-failure for each component type in the system. Currently, the reliability of the system for one, ten, and one hundred hours of operation and the mean-time-between-failure of the system are calculated. The time required for the analysis is less than one minute on the purge-pressure system. The assumption is made that the distribution of the component failures are Poisson.

SFPA is written in COMMON LISP on a PC AT equipped with a Gold Hill Hummingboard. It is implemented on top of KATE, the Knowledge-based Autonomous Test Engineer, a control, monitor, and diagnostic expert system shell under development at KSC, utilizing the procedures and knowledge base written for KATE. Currently, SFPA is a laboratory-only demonstration model. Further development of the software is planned for the future.

Pamela McVeagh, 867-3224

DL-DSD-22

## Thunderstorm Weather Forecasting Expert System

At Kennedy Space Center, the Shuttle operational weather forecasting is provided by the U.S. Air Force from the Cape Canaveral Forecast Facility (CCFF). Shuttle operational forecasting is very difficult because of the location, on the coast and on the Florida peninsula. The forecasters have tours-of-duty ranging typically from two to four years. Most of the expertise that they develop leaves with them at the end of their tours-of-duty. Shuttle operational forecasting is further compounded by the wealth of information available from conventional weather data sources and from a multitude of specialized instrumentation systems. In the process of making a short-term forecast, it is difficult to know which data sources are appropriate, much less assimilate the data.

In this context, the Thunderstorm Weather Forecasting Expert System (TWFES) Project is developing a weather forecasting aid which captures the corporate and individual expertise developed by the forecasters and also focuses their attention to anticipated events and to the appropriate data sources. An additional goal of this project is to develop in-house NASA expertise in applying expert system technology.

Arthur D. Little, Inc. (ADL) was originally selected for this contract and has completed their work. The activity is moving in-house. ADL performed a feasibility study in 1985 which recommended summer thunderstorm forecasting as the best choice in terms of benefits and in terms of appropriateness to expert system technology. The severe weather associated with thun-

derstorms affects many Shuttle operations.

ADL then developed a demonstration prototype in 1986 and continued with the first year of a research prototype in 1987. During the demonstration prototype phase, knowledge engineering was performed to determine the appropriate knowledge representation (scenarios) and control structure, and to elicit knowledge from the domain experts. A significant feature of this phase was a scenario editor which speeded the knowledge acquisition. A dozen scenarios were elaborated. The demonstration prototype was developed using an expert system shell, the Automated Reasoning Tool (ART), and ZetaLISP on a Symbolics 3640. This phase established the viability of the approach.

The research prototype was rewritten in ZetaLISP, modularized, and integrated. ART had served its purpose for initial development. More knowledge acquisition was performed during the summer. This phase established its potential as an operational forecasting aid.

During the next year, the in-house NASA team will expand the research prototype with operational knowledge about weather advisories and weather warnings, and will integrate them with the thunderstorm scenarios. It will be tested in the NASA Weather Laboratory in 1988. During 1989, the research prototype will be turned into a field prototype with full functionality and tested in the CCFF by the U.S. Air Force during the summer.

A.E. Beller and P. McVeagh, 867-3224 DL-ESS-31

## Effects of Hydration on Cardiovascular System Responses

Since the earliest human space flights, reduction in orthostatic tolerance, or a tendency to faint upon standing up, has occurred in crews postflight. From many studies conducted with crews of all human flight programs (U.S. and Soviet), we know that in large part this effect can be attributed to a loss of blood volume as a consequence of exposure to weightlessness. To further confound this condition, a potentially aggravating factor has been reported anecdotally and in the scientific literature, i.e., aerobic physical fitness seems to worsen orthostatic tolerance.

With these factors in mind, a study was designed and conducted by investigators of the KSC Biomedical Operations and Research Office to acquire specific quantification and correlation of blood volume changes in individuals of widely varying levels of physical fitness and the corresponding responses of their cardiovascular system important to the maintenance of orthostatic tolerance. This study incorporated the knowledge that short term operational and subjective benefit for this condition can be realized by oral intake of fluids a few hours before deorbit and entry to earth's gravitational field.

Sixteen healthy men (32-47 years) underwent lower body negative pressure (LBNP, which simulates the effect of gravity on the cardiovascular system) stress tests in each of three distinctly different states of hydration (protocols): 1) dehydration 4 hours after oral administration of 40 mg furosemide (a diuretic), 2) normal hydration after an overnight, 12+ hour fast (no oral intake), and 3) hyperhydration from oral intake over 3 hours of isotonic saline (flavored for palatability) equal to 2.0% of lean body mass.

The sixteen men were selected from two otherwise matched subsets according to maximal oxygen consumption (aerobic fitness) as measured by the Bruce treadmill protocol, with separations being low fit ( $\leq 42$  ml  $O_2$   $kg^{-1}$   $min^{-1}$ ) and high fit ( $\geq 50$  ml  $O_2$   $kg^{-1}$   $min^{-1}$ ).

Important measurements taken with each fluid state

and the LBNP test accompanying that state included: body weight, plasma volume and osmolality, plasma renin activity, hemoglobin, hematocrit, aldosterone; heart rate, blood pressure, thoracic impedance, stroke volume, systolic time intervals, and change in calf circumference.

From statistical analyses of these data, significant differences in plasma volume were obtained across the three fluid states, while certain other variables differed in one from the other states, but none showed consistent patterns according to fitness. Another notable finding was the compounded elevation of fluid and electrolyte control hormones by concurrent lower vascular volume and LBNP stress. This effect was not further augmented, however, by level of fitness.

These results, with discrete manipulations of body fluids, have shown quantitative orthostatic benefit from the short term increase in plasma volume and, conversely, adverse effects from acute fluid loss. Findings should assist optimization of fluid loading as an adjunct countermeasure for returning space crews. Nearly complete dissociation of these orthostatic relationships is observed from level of fitness in this cross-sectional study, which should lessen constraints upon methods to maintain aerobic fitness and muscle tone and condition in long-duration space flight.

Dr. G. Wyckliffe Hoffler, 867-2964  
Dr. Victor A. Convertino, 867-4237

MD-RES  
MD-RES

## System for Electrical Stimulation of Skeletal Muscles

The Kennedy Space Center has developed an electromyostimulation (EMS) system. This system applies sequenced stimulation currents to the four major muscle groups in the leg. Two load cells attached to a leg brace, constraining the leg to isometric contractions, measure parallel tangential torque about the ankle and knee axes. Stimulation is applied sequentially to the quadriceps, hamstrings, calf and anterior tibialis muscles in the dominant leg while

subjects rest in the supine position. Load cells were selected because they are stable, reliable, and are easy to remove and calibrate to NBS standards. Measurement of the square wave pulse stimulus current (60-Hz, 300-usec pulse for a four-sec duration) requires the use of a peak detector circuit. Torque development and stimulation current are recorded on a personal computer during each EMS session. The data acquisition system offers accurate quantification of the muscle forces and stimulation current levels used during EMS.

M. R. Duvoisin, 86-74742

MDE-NGA

## Liquid Air Pack

A new type of self-contained breathing apparatus has been designed and tested at the Kennedy Space Center. The liquid air pack was designed to replace an existing (obsolete) respiratory protective apparatus when no commercially available device was available to meet new and more restrictive requirements of crew rescue. The liquid air pack is an open-circuit, positive pressure demand system that is initially charged with 6 pounds of liquid air. The system carries the equivalent of 60 minutes of breathing air and weighs only 24 pounds. It has a low profile allowing rescuemen to enter the 20-inch square emergency Orbiter hatch. Air provided is cool and of sufficient quantity to assure positive pressure within the mask, even during high-rate work. Finally, testing is underway to secure a NIOSH certification for this system. Other planned advances include a new Dewar with a swivel liquid-pickup tube and the possible adaptation to a longer duration, closed-circuit design.

D. F. Doerr, 867-3152

MD-ENG

## Human Physiological Adaptations to Weightlessness Research Projects

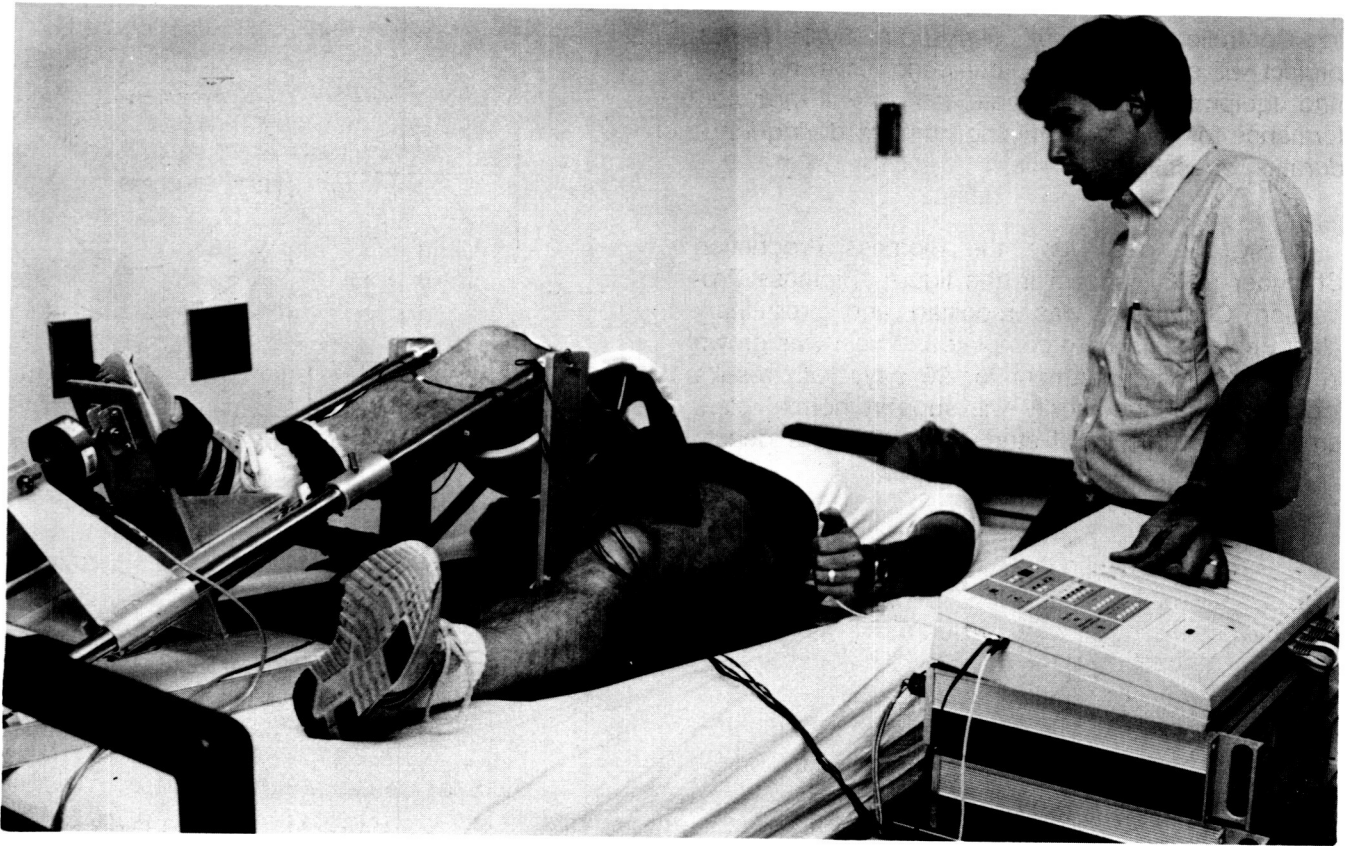
During the past year, the Life Sciences Research Office undertook two major research projects to determine the effects of long-duration spaceflight on the cardio-vascular and muscle systems in man. In addition, these studies were used as a testing ground for the development of new countermeasures designed to minimize the deterioration of muscle size and function following spaceflight.

In the first project, a model was developed for inducing muscle deterioration (atrophy) by fabricating a special bi-valve fiberglass cast which was placed on one leg of eight healthy subjects for 16 days. The second project was a joint bedrest study conducted at Ames Research Center (ARC) which lasted from June through August. In this study, eleven men from 30-50 years of age underwent 30 days of continuous bedrest in a 6-degree headdown position to simulate the effects of long exposures to weightlessness. Several new techniques used for the study of muscle structure and function were incorporated into these studies. Measurements of leg size and muscle mass were conducted with the aid of computed tomography (CT) scanning techniques. Muscle biopsy and electron microscopy techniques were used to determine ultrastructural changes such as fiber types and sizes, and various enzyme and nutrient contents. New testing procedures using a special isokinetic dynamometer were developed to determine muscle strength and fatigue characteristics for eccentric as well as concentric muscle contractions.

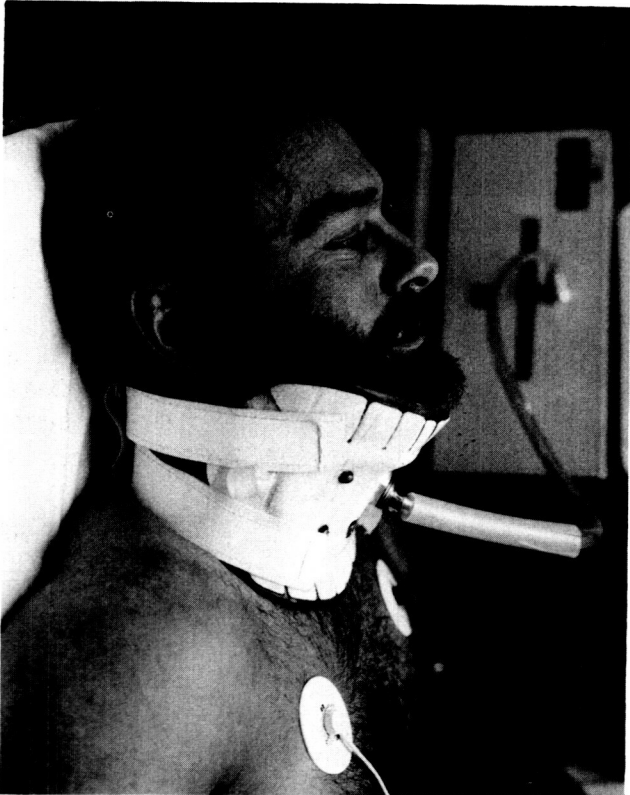
In addition to the development and use of techniques during these studies to determine the adverse effects of long-duration spaceflight on muscles, a newly fabricated leg brace and electrical stimulation system was tested in an attempt to develop a countermeasure to ameliorate muscle atrophy. In both studies, some subjects received electrical stimulation to the muscles of one leg as depicted in the

figure "Newly Fabricated Leg Brace and Electrical Stimulation System." This technique may prove effective in optimizing crew operational time by reducing the projected time required for conventional exercise during spaceflight.

Finally, the ARC bedrest study provided the opportunity to examine the effects of long-duration weightlessness on specific cardiovascular alterations which have not yet been examined from controlled, ground-based studies. The compliance of the leg veins was measured using a fabricated mercury-in-silastic strain gauge and occlusion plethysmography technique. The response of the carotid baroreflex was measured using a neck pressure chamber designed especially for Spacelab (figure "Baroreflex Neck Pressure Chamber"). These two measurements are important in assessing and understanding the adaptation of man to weightlessness since both venous compliance and baroreflex responsiveness may be associated with post-flight fainting episodes in astronauts.



*Newly Fabricated Leg Brace and Electrical Stimulation System*



*Baroreflex Neck Pressure Chamber*

Additional casting and bedrest studies will be conducted during the next year. The results from present and future experiments should provide critical information about the human physiological adaptations to long-duration spaceflight and needed development of countermeasures against adverse effects.

Dr. P. Buchanan, 867-2585  
 Dr. V. A. Convertino, 867-4237  
 D. F. Doerr, 867-3152  
 M. R. Duvoisin, 867-3152  
 A. B. Maples, 867-3152

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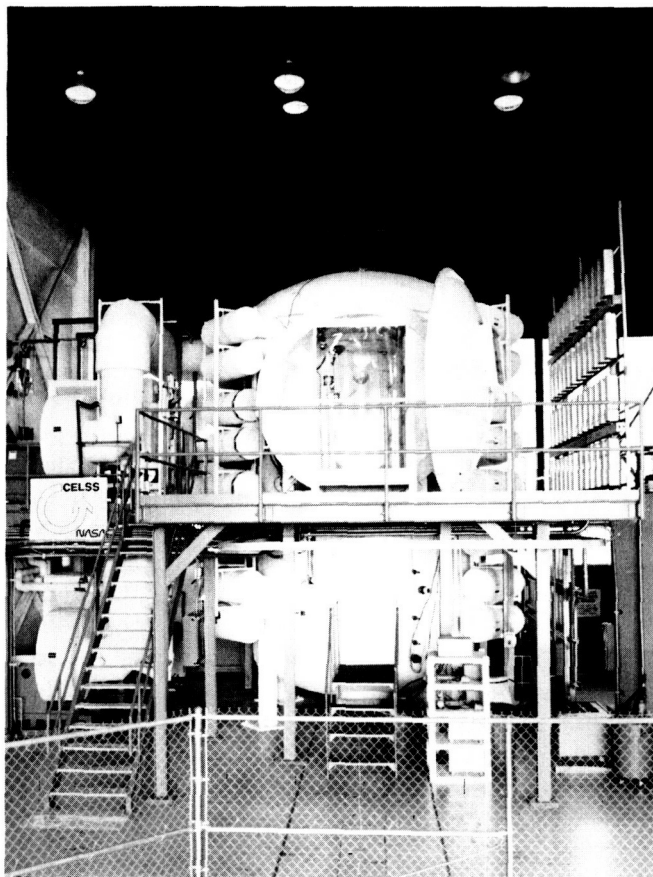
## **Controlled Ecological Life Support System (CELSS) Breadboard Project**

A major project was initiated at Kennedy Space Center in 1985 with a goal of integrating elements of a biological regenerative life support system within, or in association with, a large atmospherically sealed plant growth chamber and development of a function-

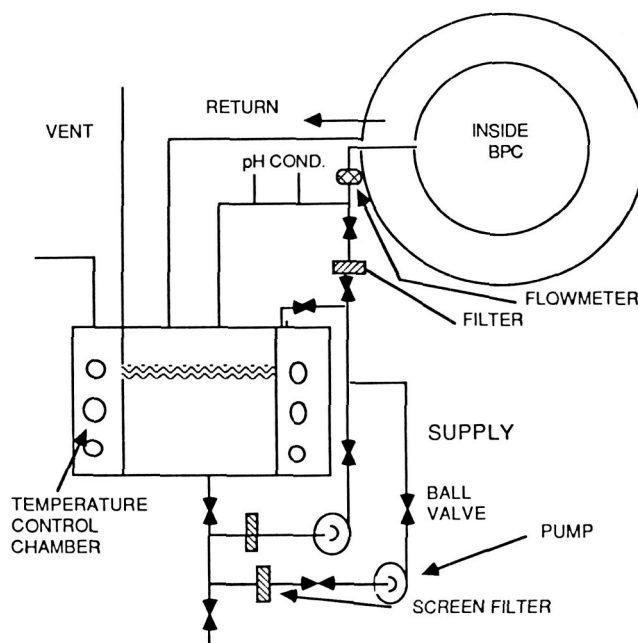


ing Controlled Ecological Life Support System. This project will scale-up laboratory bench level methods and equipment to a level adequate to test their performance for use in sustaining humans during long-duration spaceflight.

During the past year, the Biomass Production Chamber (BPC), shown in the figure "Biomass Production Chamber," was modified and preliminary plant growth tests were completed. Wheat was grown in the upper compartment for 90 days with results indicating that the facility will support normal plant growth. After this initial study, the BPC was deactivated and atmospheric control and nutrient delivery sub-systems were added. The atmospheric control subsystem is microprocessor based and it controls CO<sub>2</sub> between 300-2500 ppm and O<sub>2</sub> at 21% under sealed recirculating conditions. Concentrations are manipulated through the addition of compressed gases. The nutrient delivery subsystem is based on the nutrient film technique, and supplies solutions to the growing trays in a recycling configuration (see the figure "Schematic of Nutrient Delivery System for One of Four Tanks").



*Biomass Production Chamber*



*Schematic of Nutrient Delivery System for One of Four Tanks*

An important concern of the CELSS Program is the microbial population dynamics within various subsystems of the BPC. During preliminary wheat growth studies, the microbial ecology of the hydroponically based plant culture systems was examined. The two major goals of the microbial research program are determination of microbial population densities and community composition over time in all regions (root zone, nutrient solution, surfaces, air, filters). A major effort is planned to quantify these microbial components during baseline operation of the BPC.

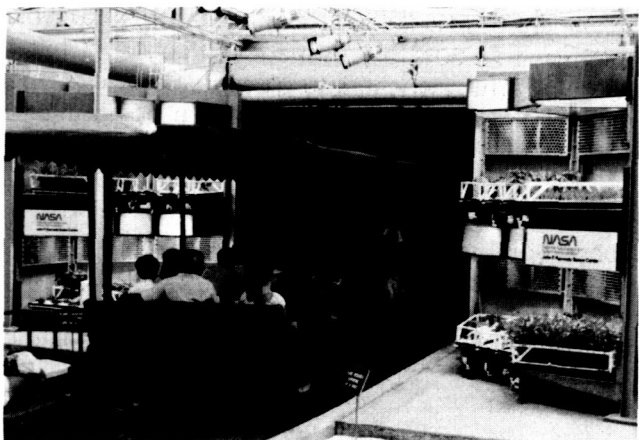
During the coming year, the BPC will be leak tested, the environmental control capabilities thoroughly tested, and at least one crop grown to maturity and the results analyzed. The activation of this unique facility is a major milestone in NASA's efforts to develop a bioregenerative system for life support during long-duration space missions.

William Knott, 853-5142

MD-RES

## EPCOT Project

A representation of the plant growing racks being used in the Controlled Ecological Life Support System (CELSS) Biomass Production Chamber (BPC) was



*Hydroponic Plant Growth System at Entrance to The Land Pavillion of EPCOT*

constructed and installed on either side of the boat ride through the Land Pavilion of EPCOT. A Memorandum of Agreement was signed between NASA and Walt Disney World that allowed for the construction of this exhibit/research facility. These racks will permit NASA to transfer, to the public, plant growth techniques that are being studied and developed for use in spaceflight, and will also allow researchers at the Land Pavilion to evaluate how various crop species grow in candidate hydroponic systems. Investigations of plant pathogens that may contaminate the roots of plants in these culture systems will also be conducted. This interchange of expertise and information between NASA and Disney is a new undertaking and hopefully will lead to a long and mutually beneficial relationship for both organizations.

William Knott, 853-5142

MD-RES

## Solar Light Transmission System

A major concern in the production of food in space as part of a Closed Ecological Life Support System (CELSS) is the provision of optimal light quality and quantity with minimal energy consumption. A project is underway utilizing a polycarbonate material which, when formed into a hollow rectangular structure, can transport light much as a pipe transports water.

A platform which is equivalent to 1/4 of the CELSS Biomass Production Chamber (BPC) has been constructed to act as a test stand. Light would normally

be provided to the platform by eight light caps, each of which would contain three 400-watt high-pressure sodium lights. These light caps have been replaced by new light caps constructed from the polycarbonate material. The new light caps are the same length and width as the old, but only 1/4 the thickness. They contain no bulbs; all light being supplied from a remote source. This system will be evaluated and tested for plant growth over the next few months.

Jeffrey Jones, 853-5142

MD-RES

## Long-Term Environmental Monitoring Program

In the area of operations and construction monitoring, several tasks that were initiated as part of the STS launch assessment activities have continued. Laboratory analyses of metals associated with different size fractions of particulate deposition have been completed and a report is in preparation. Results of a bioaccumulation study of metals in fish tissue from specimens collected in the vicinity of LC-39A and at background locations have been summarized in a draft Master's thesis, and a final report is due in early 1988. The laboratory analysis and data entry activities of a one-year fish community dynamics survey for areas near LC-39A and LC-39B have been completed. All historic and recent benthic samples have been analyzed and data have been entered into the long-term database for statistical analyses.

Long-term ambient environmental monitoring program activities at KSC proceeded, as planned, during 1986 and 1987. Ambient air quality monitoring of the Environmental Protection Agency (EPA) priority pollutants ( $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{CO}$ ,  $\text{O}_3$ , particulates) and recording of local meteorological conditions continued at the Permanent Air Monitoring Station (PAMS A). Several pieces of new equipment, including a meteorological tower, meteorological sensors, and a high volume air sampler were purchased. A summary report comparing air quality at KSC to other locations in Florida between 1983 and 1986 was prepared and presented at the annual meeting of the Florida Air Pollution Control Association. Air quality at KSC is good; however,  $\text{O}_3$  values have increased each year and are approaching maximum permissible levels.

Weekly rain sampling at the KSC National Atmospheric Deposition Program (NADP) site and the Uni-

versity of Central Florida (UCF) rain station continued. A comparative report summarizing the historic and current data from these two sites was prepared and published as NASA TM-100301.

Rainfall pH at KSC declined slightly after two consecutive years of small increases and averages approximately 4.7. Long-term water quality monitoring activities continued as planned. In general, water quality around KSC is good to excellent, and KSC has achieved zero discharge to receiving waters from its sewage treatment plants.

In the ecological research area, a wide variety of activities were accomplished during the year. The second year of evaluations for effects of beach nest temperature on the sex ratio of sea turtle hatchlings was completed in cooperation with the University of Toronto and the United States Fish and Wildlife Service (USFWS). The local office of the USFWS conducted sea turtle nesting surveys on KSC beaches and provided the data for inclusion in the long-term monitoring database. A manuscript describing turtle nesting activities at KSC was published in a special symposium publication by the NOAA National Marine Fisheries Service. Results of the KSC manatee distribution and abundance surveys have been summarized in a manuscript for journal publication. In spring months (March, April), population levels exceed 250 individuals.

The computerized Geographical Information System (GIS) was installed and integrated into the environmental database program. Digitized maps of terrestrial vegetation communities, seagrass beds, and shellfish beds were prepared for the National Park Service to complement those previously completed for KSC. Vegetation transects in a recently burned area were resampled to provide data on the effects of fire. Seagrass transects and plots were surveyed, as planned, for species composition, density, and biomass. The results of the Florida Game and Fresh Water Commission funded study of gopher tortoise and habitat relationships were analyzed and developed into a draft manuscript which is undergoing revision.

William Knott, 853-5142

MD-RES

## Biomass Conversion

The long-range goal of biomass processing research in the Controlled Ecological Life Support Sys-

tem (CELSS) Program is maximal conversion of inedible plant residues into food or other useful products. Initial research at KSC has examined the enzymatic conversion of cellulose, a poly-saccharide which comprises 25-30% of the inedible fraction of hydroponically grown wheat, into glucose. Selected hyper-producing mutant strains of fungi are being used to produce the cellulase enzyme. Concurrent and future studies in biomass conversion include enzymatic conversion of hemicellulose, utilization of soluble carbohydrates, recovery of soluble inorganic nutrients, and conversion of sugars to mycoprotein.

William Knott, 853-5142

MD-RES

## Survey of Exercise Equipment for Possible Application to Space Station

A comprehensive survey has been completed of existing exercise equipment presently on the market. This survey was made to assist the Life Sciences staff at the Johnson Space Center in defining the astronaut exercise provisions to be placed aboard the Space Station. The survey focused upon the examination of the basic force generator or the principle used by each piece of equipment in its operation. All items were then classified into two categories, "gravity-dependent" or "gravity-independent." Those items using "gravity-independent" principles were then examined in detail. The computer data base developed includes: the description of the equipment; its method of operation; its weight and space occupied; the manufacturer; cost; and the name and address of a contact for follow-on discussion for the items. Following the initial effort, the survey is being maintained through periodic up-dates as new items of exercise equipment reach the market. The initial survey and two updates have been completed this year. This data base is a unique resource because it represents the only known compilation of data on exercise equipment that are being offered for sale by reputable manufacturers in the United States.

Dr. Victor A. Convertino, 867-4237

MD-RES

## Aquaculture

In 1986, a project was initiated to evaluate aquaculture as an integral part of the Controlled Ecological

Life Support System (CELSS) Program. Aquaculture represents a potential component of CELSS since it can provide protein in the form of fish tissue, plant biomass, and algae. Waste minimization can be accomplished by feeding inedible plant biomass, table scraps, and byproducts of bacterial and fungal conversion processes to the fish, incorporating plant biomass in the biofilter, and recycling nutrients from fish metabolites and waste food. It will also contribute to control of the oxygen-carbon dioxide balance.

Initial program development included a literature search and the testing of the feasibility of growing wheat and fish (*Tilapia aurea*) in a small-scale combined system. Emphasis is currently being placed on linking a fish production system, a biological filter for control of ammonia, and a plant production system. The conversion of inedible plant and mycelial biomass into useable high-quality fish protein and nutrients for plant growth is also being studied.

Future efforts will include expansion of the combined aquaculture/agriculture system to include different plant and animal species in various combinations and under a variety of growth regimes. This will require the design and construction of hardware and instrumentation needed to optimize biomass production. Further work will be done in the area of biomass conversion including various diet compositions and research into the utilization of plant biomass as a biofilter component. Consideration will also be given

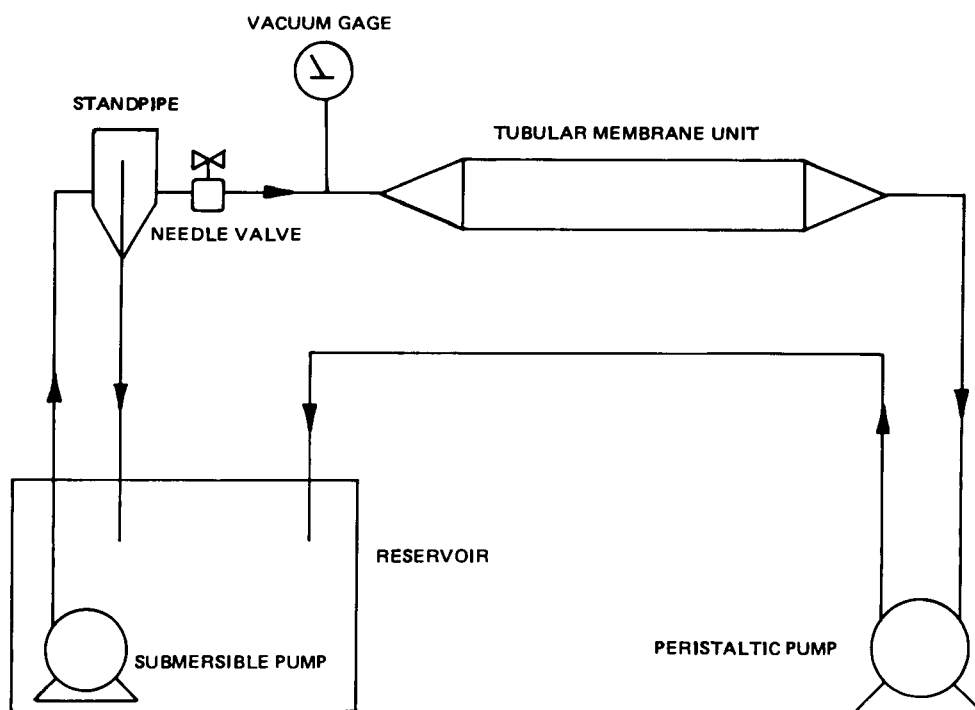
to new plant and fish species selection, algal culture, and breeding of various tilapia species and their hybrids.

William Knott, 853-5142

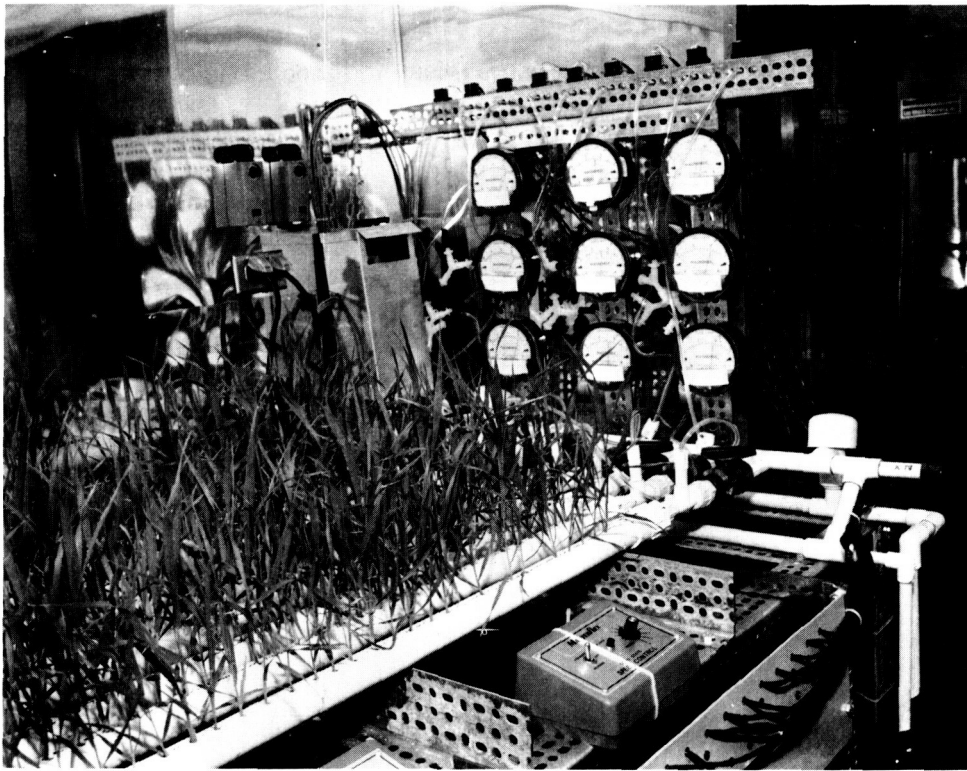
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## Tubular Membrane Plant Growth System

A pressure monitoring and control system has been developed to support the tubular membrane plant growth unit which was designed to deliver nutrients and water to plants under microgravity. Because control and monitoring of pressures within the unit are probably critical to its operation and ability to control solution flow, a stand-pipe system was developed to partially overcome the effect that gravity has on the operation of the unit on Earth. A valve and gage permit the monitoring and control of the negative pressure within the system which controls the capillary flow of water through the membrane. The figures "Schematic of the Tubular Membrane Plant Nutrient Delivery System With Standpipe, Monitoring and Control Capabilities" and "Young Wheat Crop With Standpipe, Gages and Valves" depict the system.



*Schematic of the Tubular Membrane and Control Capabilities*



*Young Wheat Crop With Standpipe, Gages and Valves*

Alternate microporous materials are also being evaluated as a substitute for the membrane tube in these units. These materials include microporous plastics, ceramics, and sintered metals which make assembly simpler and would be more durable. Crops are currently being grown in units utilizing some of these materials.

William Knott, 853-5142

MD-RES

## **Controlled Animal Nutrients Delivery System (CANDS)**

The objective of the Controlled Animal Nutrients Delivery System (CANDS) project is to provide investigators with a system capable of supplying research rodents with a sterile, nutritionally complete, and balanced diet (including water) in a manner that facilitates intake monitoring and maintains biocontainment

capabilities while in microgravity. CANDS has approached the problem of nutrient delivery and monitoring by developing an integrated, two-component system that combines hardware and diet to achieve desired results. The hardware incorporates a passive delivery system which interfaces with existing flight hardware (the Animal Enclosure Module, shown in the figure "Diet Delivery Concept for the Animal Enclosure Module") and requires minimum crew interaction to accurately monitor daily animal intake. The hardware is also designed to function in environmental conditions similar to those found in the Shuttle middeck during flight, and to provide sterile diet delivery while maintaining biocontainment and assuring animals achieve ad lib intake. The diet is fed in high-moisture form (60-65% water) and utilizes semi-purified ingredients which allow for flexibility in formulation. With this flexibility, single nutrients, or nutrient ratios, may be altered as experiment protocols require. The cohesive nature of the high-moisture diet make it ideal for use in microgravity and minimizes waste. The present diet was formulated to meet Nutritional Research Council requirements, and has supported "normal" rat growth

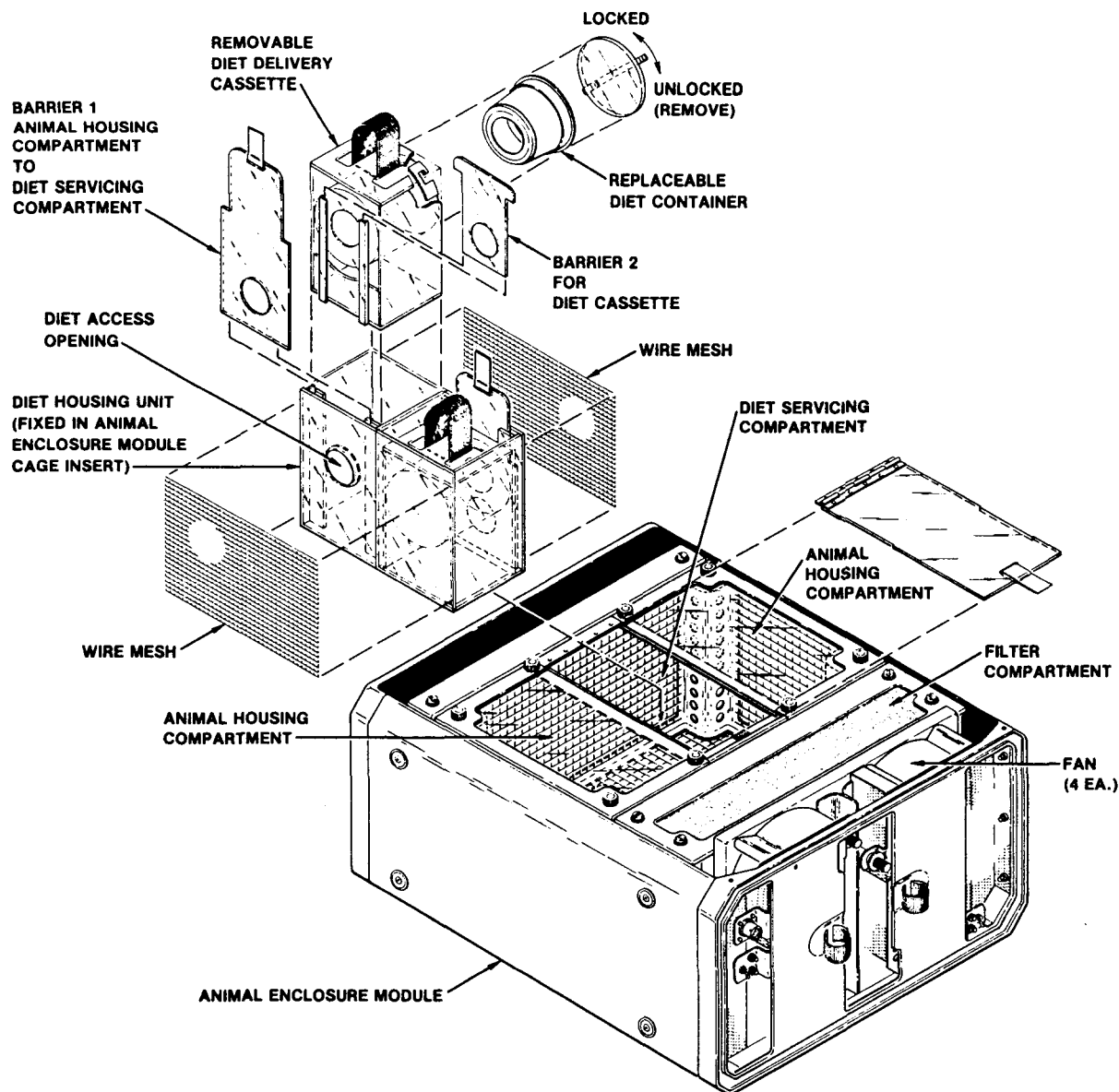
over two short-duration studies.

A preliminary biocompatibility study conducted during a "mission simulation" compared conventional housing with the prototype hardware. Results indicated that all systems were equally capable of supporting "normal" rat growth and demonstrated the hardware's ability to allow ad lib consumption to be monitored in a quantitative manner. CANDS evaluations in simulated micro- and hyper-gravity onboard a KC-135 allowed for modifications to be incorporated into the hardware design and further demonstrated the system's ability to maintain biocontainment and meet research objectives.

Upcoming studies will focus on: 1) Further characterizing rat performance when fed the present high-moisture diet formulation and when housed in the prototype hardware for extended periods of time, 2) testing diet stability when exposed to vibration profiles similar to those found in orbit forward bulkhead mid-deck lockers, 3) collecting ground-based, baseline data for future comparison to animal performance in microgravity, 4) determining shelf life (sterility and nutrient stability), and 5) evaluating a diet packaging and delivery system for potential use for inflight diet mixing.

William Knott, 853-5142

MD-RES



*Diet Delivery Concept for the Animal Enclosure Module*



# OPERATIONS

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## Remote Maintenance Monitoring System

The Launch Processing System (LPS) at the Kennedy Space Center utilizes over 200 Modcomp computers to perform launch critical functions involving the Space Shuttle and ground support equipment. Hard failures seldom present troubleshooting challenges; however, intermittent failures consume vast quantities of manpower and time. To attack this problem, the Remote Maintenance Monitoring System (RMMS) project is developing a prototype system to facilitate maintenance of the Modcomp computers. The basic Remote Maintenance Monitoring System (RMMS) concept integrates three activities to address the maintenance problem: continuous real-time monitoring of hardware, integration of diagnostic data, and automation of the diagnostic process. Because of the lack of diagnostic data, maintenance is fundamentally difficult; RMMS alleviates this situation.

The RMMS prototype demonstrated the automated diagnostics concept in April, 1987. It consisted of a Modcomp computer as the test article, a sensor implant, and a Diagnostic Expert System (DES). The demonstration consisted of detecting and diagnosing induced parity errors and power supply fluctuations. The sensor implant monitored 24 digital signals (parity error signals) and 14 analog signals (power supply voltages) in the Modcomp computer. All of the sensors were located on sensor pods which were optically isolated from the sensor implant to prevent deleterious effects to the Modcomp computer. The sensor implant monitored the Modcomp computer for presence of any one of 38 predefined abnormal, but not necessarily erroneous conditions. When one or more abnormality was detected, the sensor implant would initiate data collection, capturing the 1024 frames of all the monitored signals at 100-nanosecond intervals. This failure data was then transmitted to the DES via RS232 for diagnosis.

The DES, written in Franz LISP, consisted of an inference engine, a user-interface, a communication module, and a set of diagnostic rules. The forward-chaining inference engine used a conflict resolution algorithm to choose the most specific rule between

competing rules. The user-interface was designed for the novice user and required no keyboard entry. All program control was via a three-button mouse and pop-up menus. The user-interface displayed a schematic representation of the Modcomp and graphically highlighted the active sensors. The communication module controlled data transmission between the DES and the sensor implant; it also performed initial data reduction before the inference engine was invoked.

To demonstrate the capability of RMMS, parity errors and power supply voltage fluctuations were induced. The DES informed the user that an erroneous condition existed in the Modcomp and displayed the location of the active sensor. The user then initiated diagnosis through the mouse-menu interface. The final diagnosis appeared at the bottom of the screen and a detailed explanation of the diagnostic process was printed on a local printer.

The prototype demonstrated the RMMS concept in a limited, but extremely useful, diagnostic domain. Parity errors and power supply fluctuations are frequently responsible for Modcomp failures that cannot be duplicated in a troubleshooting environment. Thus, the ability to monitor Modcomp computers in real time is extremely valuable to the diagnostic process. However, the prototype only demonstrated a single thread of a complete RMMS. An implemented RMMS, would monitor all the Modcomp computers in the set. The demonstration of the prototype marked the end of the initial research and development phase and the beginning of RMMS II.

### RMMS II:

Having completed the concept demonstration phase, the next phase (RMMS II) includes the development of a prototype that can be implemented and extended to include other data sources (sensor implants). The focus of Phase II is the development of a Modcomp Memory Dump Analyzer (MEDUSA). This was chosen for the following reasons:

- Memory dump analysis is often the first step in the diagnostic process.

- Memory dumps from all the Modcomp computers connected to the Common Data Buffer can be analyzed with only one physical interface with the hardware. Thus, one implant can provide considerable diagnostic leverage with a large number of computers.
- The expertise to diagnose Modcomp memory dumps is not captured in any manuals or documents, and the number of personnel trained to perform Mod-comp memory dump analysis is decreasing.

The Memory Dump Analyzer has three important implications: it allows interactive development with the system engineers of an acceptable interface; it provides the systems engineers with a tool for computer-aided analysis of a memory dump, and facilitates development of the automated analysis capability.

#### FUTURE PLANS:

Future development will extend RMMS to diagnose more types of failures and monitor a distributed network of multiple Modcomp computers. With assistance from MITRE Corporation, NASA plans to develop a hybrid model-based/rule-based Diagnostic Expert System, using KEE, for diagnosing failures of Modcomp computers. The RMMS project will continue to explore ways of improving diagnostic capability for maintaining LPS Modcomp computers using expert systems.

L. G. Simpkins, 867-3926  
J. R. Rogers, 867-3926  
J. E. Madden, 867-8108

TE-LPS-1  
TE-LPS-13  
TE-LPS-13A

## Wideband Video Microwave System

Microwave systems with a wide band-width, flat frequency response, fast rise time, and low distortion are required by the University of Florida in lightning research at the Kennedy Space Center. A standard 4.5-MHz video bandwidth microwave system and an operating frequency of 10.525 GHz has been modified as a prototype. A bandwidth from 1 Hz (measured) to 8 MHz, flat frequency response, upper 3-dB frequency of 13.8-MHz Gaussian rolloff, and a fast rise time has been achieved. Distortion is less than 1%, slightly

above 5 MHz, and higher above this frequency. The System has video input and output voltages of 1-volt peak-to-peak. These requirements were specified (bandwidth improved) in the Wideband Video Microwave System specification.

Included in the specification are innovations, by NASA, affording versatility and enhanced commercialization for use of this system in transmission of data signals or TV video. (Broadcast quality affected by design for wide bandwidth; however, picture resolution is still considered good).

Four to five microwave links will be initially required and ultimately, up to ten, in the research project. To eliminate interference between links, three separate frequencies: 10.1-, 10.25-, and 10.4-GHz were specified within the bandwidth (10 to 10.5 GHz) of the microwave parabolic antennas. Only a single frequency was previously provided by the manufacturer.

Since rainfall attenuation was of serious concern, the power output was specified as 100 mw rather than the 35 mw in the original system. This power has not previously been available from the manufacturer. In addition, a fade margin control was included in the specification in response to NASA's concern for rain attenuation.

The System is provided (specified) with 50-ohm input and output impedances, transmitter and receiver, respectively, for instrumentation while retaining the 75-ohm video input and output impedances for standard TV signals.

A receiver rack mount design, with shielded enclosure attached to rear of standard 19-inch panel, is specified for allowing rack installation in place of using the independent cabinets normally supplied.

IF and RF level threshold outputs will also be provided on the rear of the receiver.

Another improvement of the system included; provision of a weatherproof remote head, which included two hermetically sealed connectors and port for low-pressurization with nitrogen. This is required for preventing moisture and condensation in the RF head and the microwave parabolic antenna feed.

The manufacturer is supplying as standard; the remote RF head (improved), the receiver rack mount



design as "Fixed System," and system operating over a frequency range as the result of NASA's specifications for the Video Microwave System.

In addition, development of a possible patent for commercialization independent of the original requirement for this system is planned.

A. Wolf Newman, 867-3436

CS-PSD-3A

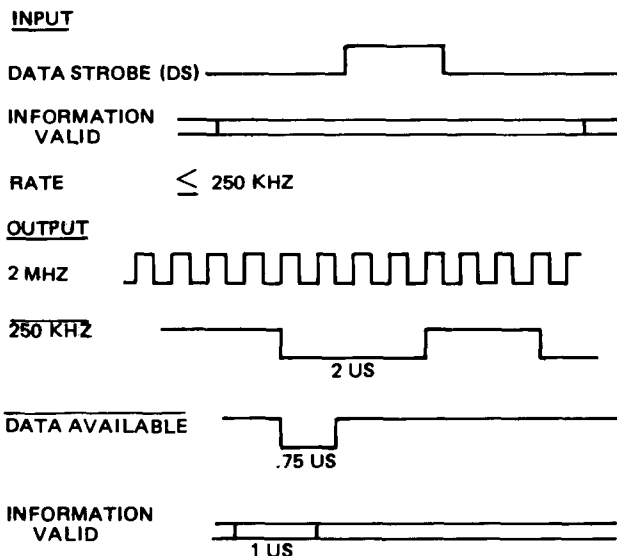
## Advantages of Employing LSI/VLSI Technology

At first glance, the advantages of using large or very large scale integration (LSI/VLSI) in electronic designs may not be apparent. However, the advantages could be tremendous, and a comparison of a circuit design using two implementation schemes could make this very apparent.

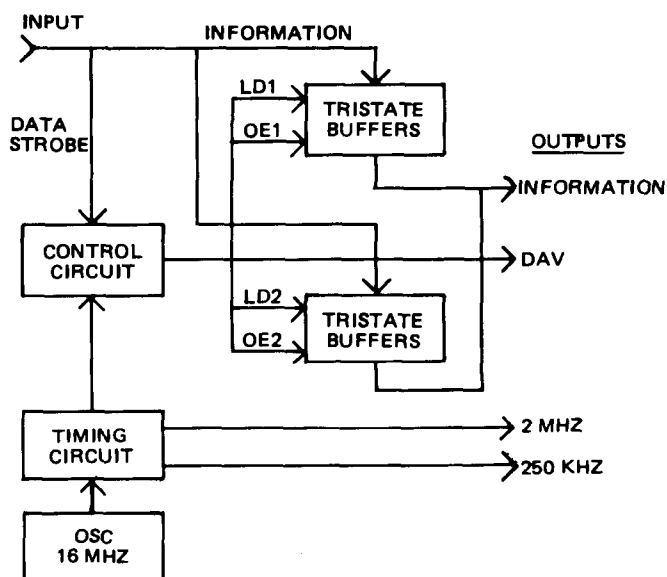
Recently, in the Expendable Vehicles Operations Directorate at KSC, the need for a different input interface to an existing system was required. The system is located in the Hangar AE Telemetry Station. It will be used to accommodate the data recording requirements for the upcoming checkout and launch of the Delta 181 launch vehicle. This system is constructed on a modular basis and employs removable boards. The new interface is a digital circuit mounted on a system board. This new board will be used in lieu of the old input board.

The requirement was one of synchronizing an input to a prescribed output rate and thruputting the received data. The input signals and required output signals are illustrated in the figure "Input/Output Signals." The inputs are digital in nature, TTL compatible, and consist of one strobe signal and 22 parallel information bits. The outputs are the information bits outputted (when available) at a 250-Kilohertz rate synchronized to an outgoing 2-Megahertz clock. A 0.75-microsecond data available pulse (DAV), when required, along with a 250-Kilohertz clock, are also outputted with the phase relationship as shown.

A block diagram of the interface is illustrated in the figure "Interface Block Diagram." The tristate buffers were employed because of their immediate availability. A basic oscillator of 16 Megahertz, along with digital counters and gates in the timing circuit, provide

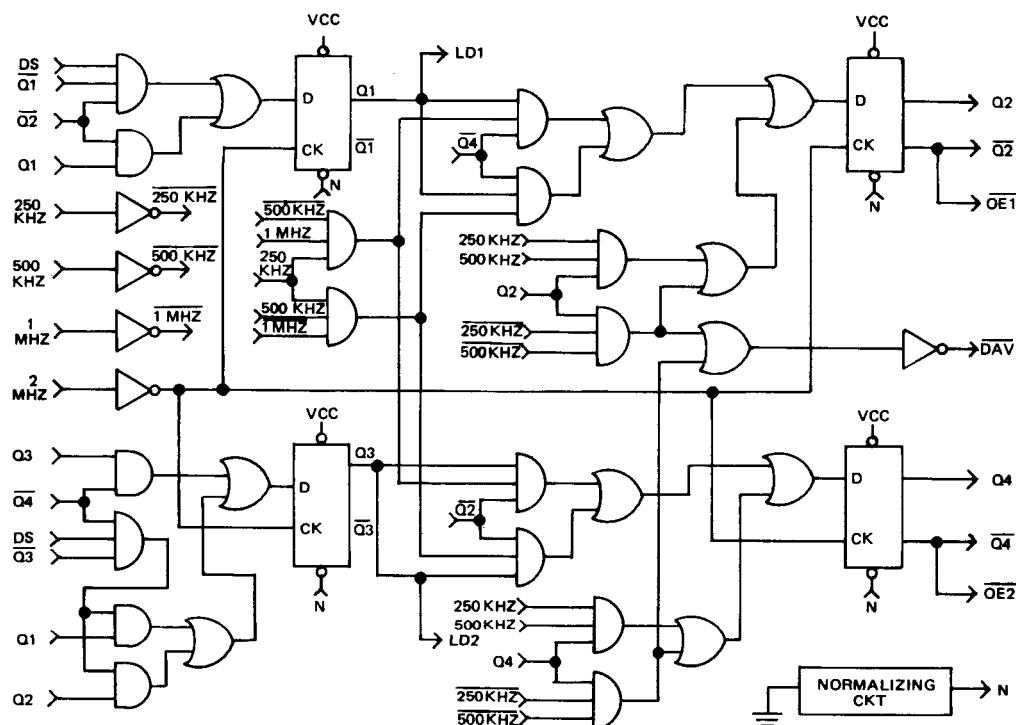


Input/Output Signals



Interface Block Diagram

the required timing clock signals. The nucleus of the design is the control circuit, whose function is twofold; to store input information and output it at the required rate along with the data available pulse. This circuit requires a sequential logic design which was done using flip-flops along with a paralleled clocked tech-



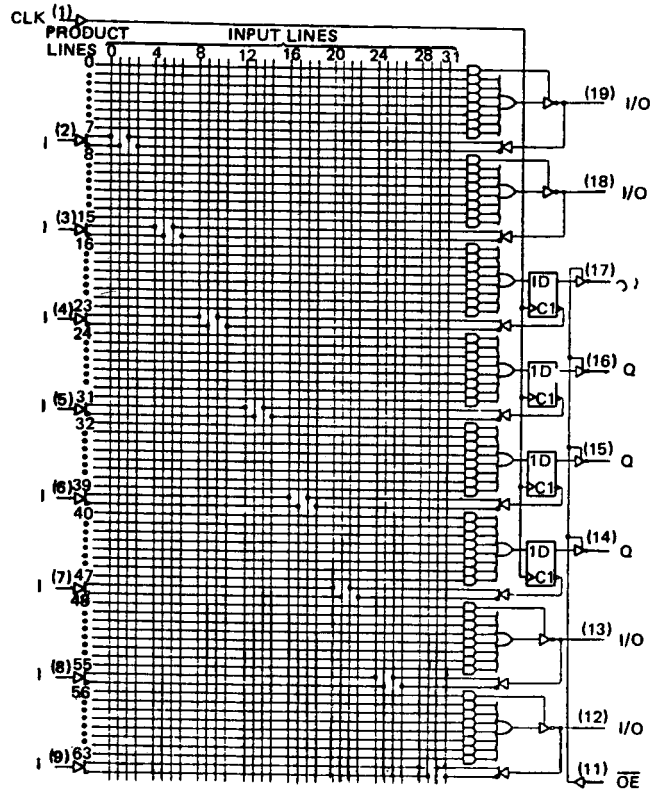
Control Logic Circuit

nique. D-type flip-flops were used, and their use will be apparent as the write-up continues. The logic drawing of the control circuit appears in the figure "Control Logic Circuit." To implement this circuit using small scale integration (SSI), the following chips would be required:

Type	Quantity
74LS04	1
74LS08	1
74LS11	4
74LS32	3
74LS74	2

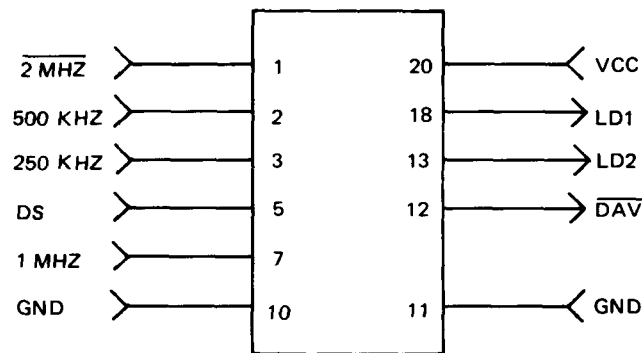
A total of eleven 14-pin, dual, in-line chips are required for implementation. Looking at the logic drawing further, circuit minimizing would not produce appreciable component reduction. However, using an LSI device, and because of the design technique employed, the circuit could be implemented using one 20-pin, dual, in-line chip.

This chip is defined as a programmable logic array, and is designated as a PAL 16R4 type. The circuit structure of this PAL is contained in the figure "High-Performance Impact PAL circuit." As shown, the device has four D-type flip-flops having a common clock along with four enabled outputs. The gating structure



High-Performance Impact PAL Circuits

accommodates eight external inputs and eight internal inputs. There are also four independent outputs from the gating structure. This overall structure makes this chip very versatile from a design utilization standpoint. The manner in which this chip was configured to implement the control function is illustrated in the figure "PAL 16R4 Configuration." The Boolean expressions used to program the chip are contained in the figure "Boolean Programming Expressions." For the final design, the timing circuit, illustrated in the figure "Interface Block Diagram," was implemented using a 16R6-type PAL.



*PAL 16R4 Configuration*

$$\begin{aligned}
 Q1 &= DS \cdot \overline{Q1} \cdot \overline{Q2} + Q1 \cdot \overline{Q2} \\
 Q2 &= 250 \cdot \overline{500} \cdot 1M \cdot Q1 \cdot \overline{Q4} \\
 &+ 250 \cdot 500 \cdot \overline{1M} \cdot Q1 \cdot \overline{Q4} \\
 &+ 250 \cdot 500 \cdot Q2 \\
 &+ \overline{250} \cdot \overline{500} \cdot Q2 \\
 Q3 &= DS \cdot Q1 \cdot \overline{Q3} \cdot \overline{Q4} + DS \cdot Q2 \cdot \overline{Q3} \cdot \overline{Q4} + Q3 \cdot \overline{Q4} \\
 Q4 &= 250 \cdot \overline{500} \cdot 1M \cdot Q3 \cdot \overline{Q2} \\
 &+ 250 \cdot 500 \cdot \overline{1M} \cdot Q3 \cdot \overline{Q2} \\
 &+ 250 \cdot 500 \cdot Q4 \\
 &+ \overline{250} \cdot \overline{500} \cdot Q4 \\
 LD1 &= Q2 \\
 LD2 &= Q3 \\
 DAV &= (\overline{250} \cdot \overline{500}) \cdot (\overline{Q2} + \overline{Q4})
 \end{aligned}$$

#### *Boolean Programming Expressions*

The advantages of this minimization exercise are as listed:

1. Reduced components

2. Reduced packing density
3. Reduced power consumption
4. Reduced Circuit Checkout (Time and Complexity)
5. Assembly Reduction (Labor and Material). In this case approximately 204 terminal wire wraps were dispensed with.
6. Improved circuit quality
7. Improve circuit reliability

In the first five listed items, a considerable cost saving could be realized in fabrication assembly and checkout. The larger the production, the greater the cost savings. The last two are associated with the manufacturing process and compaction of the components used. This, along with the reduction of human intervention in the assembly of the circuit, will certainly improve quality and reliability.

A.J. Ordóñez, 853-2769

CV-DSD-1A

## **Smart Processing of Real Time Telemetry (SPORT) Project**

The Spacelab and Experiments Division of Payload Operations at NASA's Kennedy Space Center has developed a real-time data distribution network. This network is for use in the integration and functional checkout of scientific payloads prior to their launch on the Space Shuttle. The Smart Processing of Real Time Telemetry (SPORT) Project merges high-speed symbolic LISP processors and personal computers to existing payload checkout equipment via a 10-Mbit/sec local area network.

The backbone of the SPORT system is a local area network that follows the IEEE-802.3 network standard known as Ethernet. Existing payload checkout equipment are attached to the network via Network Control Processors. These processors are used to encapsulate telemetry information into SPORT protocol packets that are routed over the network via DARPA standard Internet Protocol (IP) and Transaction Control Protocols (TCP). Network Application Processors then remove these packets for use by user application programs.

Currently, two classes of machines are being used as Network Application Processors, IBM PC/AT's for slower applications and SYMBOLICS 3670's for high-speed applications. The PC's low-level interface routines are written in 8086 assembly language and the C

language while the high-level data analysis portions are written in Goldhill COMMON LISP. The high speed applications programs are written in Symbolics COMMON LISP.

The SPORT system distributes the processing power over many different computers on the network. The advantages of this architecture have been many: it allows computer processing power to be added as it is needed; it allows for a variety of programming environments to coexist providing flexibility; it provides isolation between application software and spaceflight hardware; it allows commercially available software like Goldhill COMMON LISP and expert system building shells to be easily integrated into the system; it allows the science community to use the same kind of computer hardware at Kennedy as they have available at their base of operation. An added advantage is that the application software is developed by the user, therefore, the expertise on how the system works resides in the operations group and not in a design agency.

J. Dumoulin 867-3526  
Tracy A. Bierman, 867-3526

CS-ISO  
CS-ISO

## Automatic Test Equipment Expert Aid System

The Launch Processing System (LPS) at the Kennedy Space Center is made up from over 3000 individual Line Replaceable Units (LRU). It is the responsibility of the Intermediate Level Maintenance Facility (ILMF) to test, repair, and verify these components. A large percentage of these components lend themselves to be tested and verified at the ILMF, using Automatic Test Equipment (ATE). Presently, the ILMF uses two major ATE systems to test and verify those components within the LPS that are suited for automatic test. Specifically, these systems are the Genrad 1796 functional printed circuit board test system and a NASA enhanced Tektronix 3270 system that performs as a functional high-speed printed circuit board test system. The task of developing the Test Program Sets (TPS) that these systems use to perform these tests and verifications is both manpower and time intensive. The ATE Expert Aid project is developing a product to facilitate the development of these TPS's for the Genrad ATE. This product is designed to be useful to the seasoned, as well as the novice, ATE engineer. The fruits of this project will be a substantial

reduction in the TPS development time and more comprehensive standardized automatic test packages.

This expert system will reside on-line with the Genrad software development station as a "smart" front end. The hardware will consist of PC-AT workstations that will communicate with the Genrad PDP-8 by an interface that is presently being designed at the Kennedy Space Center. The utilities of this system will include: an on-line data base of reuseable Genrad code, a context sensitive full-screen editor, an on-line knowledge base of Genrad automatic test processes, and a Genrad TPS development fact and rule base. These data and knowledge bases will be accessed and manipulated by three major sets of software. The data bases will be controlled by a modern, high-speed, high-capacity relational data base management system called Dataflex. The knowledge base will utilize an object oriented inference engine called Goldworks. Goldworks also provides for both forward and backward chaining within the knowledge base. The link to the user will be a menu-driven, windowing software package that will be embedded within Wordstar 2000. The fact base is near completion and the first workstation is undergoing hardware integration and checkout.

Future enhancements to this system will be realized by the continuous growth of the reuseable code bank and rule base. In addition to this, this expert system approach to TPS development will be applied to the other Automatic Test Systems at the ILMF. These expert systems will continuously improve test and verification of LPS components at the Kennedy Space Center.

M. J. Lougheed, 867-4946

TE-LPS-13A

## Liquid-Vapor Flow Under Zero-Gravity

Research performed by the University of Illinois under Contract NAS10-11153 has fulfilled the primary objective of developing a methodology and the establishment of an earth-based facility for studying the dynamics of liquid-vapor flow under 0-g environment. A theoretical analysis has shown that the dynamics of an isothermal, steady, fully developed, turbulent liquid-vapor flow in a straight conduit of constant cross section at 0-g is identical to that of a mixture flow consisting of neutrally buoyant, immiscible drops in water at earth gravity. An experimental flow facility

using n-butyl benzoate drops in water has been fabricated, tested, and is fully operational. A modern data acquisition and processing system, funded mainly by a separate source, has been installed and is also fully operational.

Frictional pressure drop data for fully developed, turbulent flow of water-benzoate mixture in a 45 mm x 45 mm square duct have been obtained. The flow Reynolds number,  $Re$ , (based on the combined flow rate of water and benzoate, hydraulic diameter of the square duct and water viscosity) and the range of the volume fraction of benzoate drops, used in the experiments are:

$Re$ : 84,000	37,000	22,000	19,940
$\alpha$ : 0-1.50%	0-3.35%	0-5.56%	0-23.0%
$Re$ : 14,930	9,960		
$\alpha$ : 0-30.5%	0-46.0%		

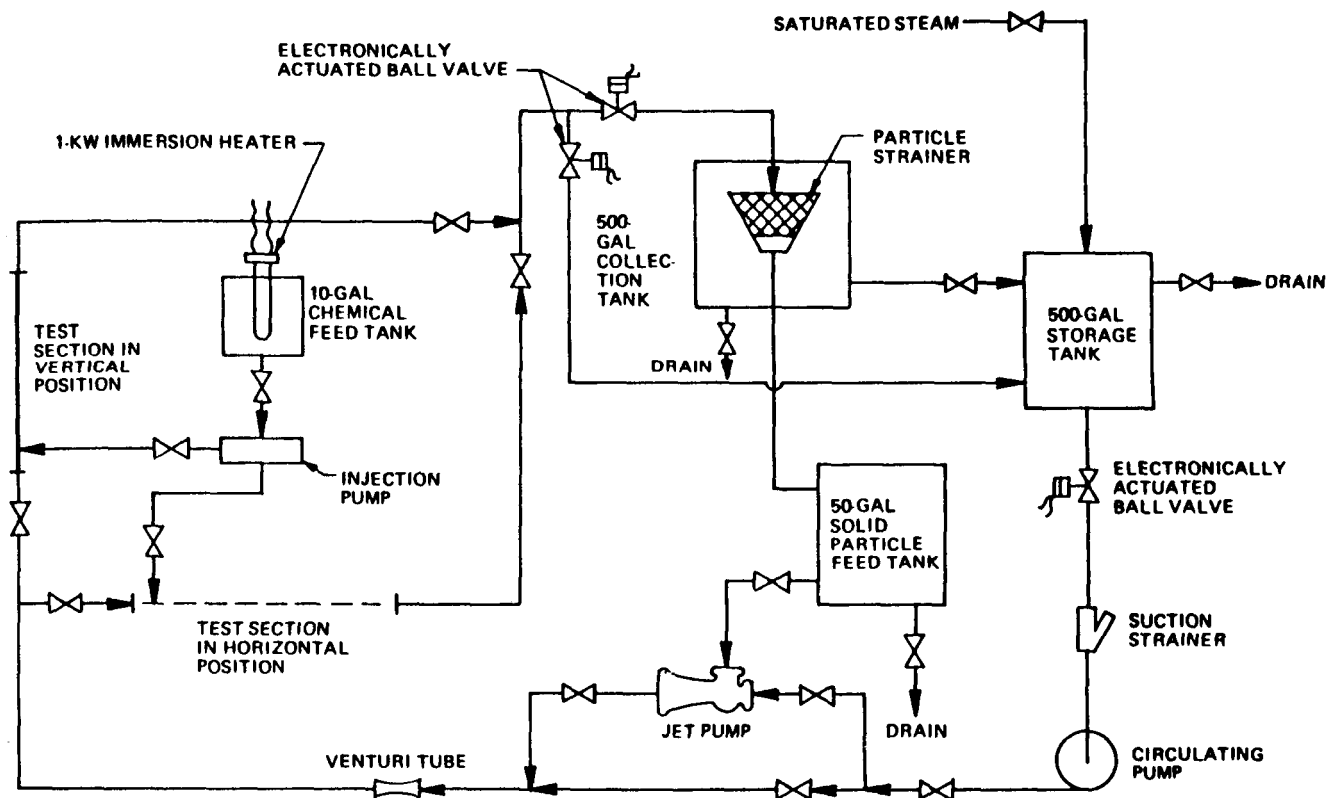
The flow regime was examined by an electric conductance probe and was found to be dispersed in all

cases. There was no flow regime transition. The size distribution of drops was also measured for  $Re = 19,940, 14,930$  and  $9,960$  using flash photography. Foremost among the findings is that, for a fixed combined volumetric flow rate of water and benzoate, the measured frictional pressure drop is unaltered even by very large changes in the volume fraction of benzoate drops and their size distribution.

The result has immediate applications for the transfer of propellant in orbit and the design of heat rejection systems of space stations. It can be used to determine the pumping requirement for liquid propellant transfer lines and for the assessment of flow resistance in the heat dissipation system where boiling of refrigerant occurs. The pressure drop due to a fully developed liquid-vapor flow in ducts of constant cross section at 0-g is identical to that of liquid flow alone at the same total volumetric flow rate. The case of developing flow is currently under study.

F. N. Lin, 867-4181

DM-MED-11



*Two-Phase Flow Loop for Simulating Liquid-Vapor Flow Under Zero-G Environment*

# FIBER OPTICS

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## Phase-Stable Transmission of Timing Information Via Fiber Optics

Multimode, fully graded, index optical fibers of 50/125-micron size were used to transmit 2- to 50-mega-bit-per-second, high data rate (HDR) digital data and clock signals over separate fibers at Kennedy Space Center for a distance of approximately ten kilometers, or six miles, without excessive phase variation, or "skew."

Field test results indicate a favorably small, long-term observable clock/data skew of less than one (1) percent of the bit interval at the highest bit rate of 50 megabits per second, including the phase variation contribution of the electronics. The optical signal traveled most of the route underground within a single optical cable installed in the KSC duct bank system. Plesscor 1300-nm hybrid optoelectronic modules were used in the transmitter and receiver.

The KSC experiment proved the feasibility of transmitting wideband data and clock signals over separate multimode optical fibers without "bit slip" problems, to meet the performance requirements of proposed space vehicle payload checkout networks. This dual-fiber technique has been utilized for over four (4) years at KSC to support Spacelab Payload Process-

ing, but the phase stability of the optical fiber was then masked by the relatively poor performance of first-generation discrete optoelectronics.

It has now been shown that new broadband optoelectronics using hybrid circuit technology can permit the utilization of phase-stable properties of optical fiber. A demonstrated application is the use of this technology to obtain low clock/data skew in data communications configurations utilizing separate clock and data channels. It may also possibly be used to transmit multiple parallel data channels and clock, such as in high speed data bus applications where phase skew is important, but this was not tried in the KSC experiments.

Possible applications of this approach include the transmission of timing information between isolated equipment sites, for radio astronomy, communications, telemetry, and radar system use. First-generation, single-mode optical fiber is reportedly being used by JPL at the NASA Deep Space Tracking Network in Goldstone, CA, in experiments to synchronize antenna sites up to 14 kilometers apart. There are potential timing application for optical fiber at KSC to (1) synchronize doppler weather radar sites for use in prelaunch weather forecasting and (2) to collect real-time triangulated information on lightning strikes.

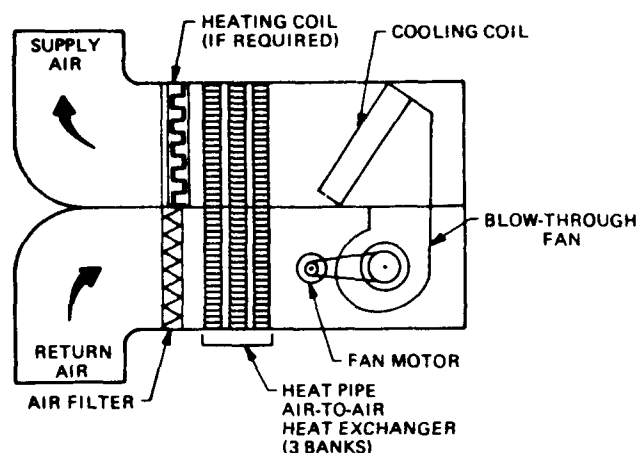
Ray Barcklow, Jr., 867-4548

DL-ESS-12

# TECHNOLOGY UTILIZATION

## Feasibility Analysis of a High-Efficiency Dehumidifier Air-Conditioner Using Heat Pipes

The idea of using heat pipes in between the supply-air duct and return-air duct in conventional air-conditioning units promises to be a cost-effective way



*Schematic of an Air Handling Unit With Three Banks of Heat Pipe Air-to-Air Exchange*

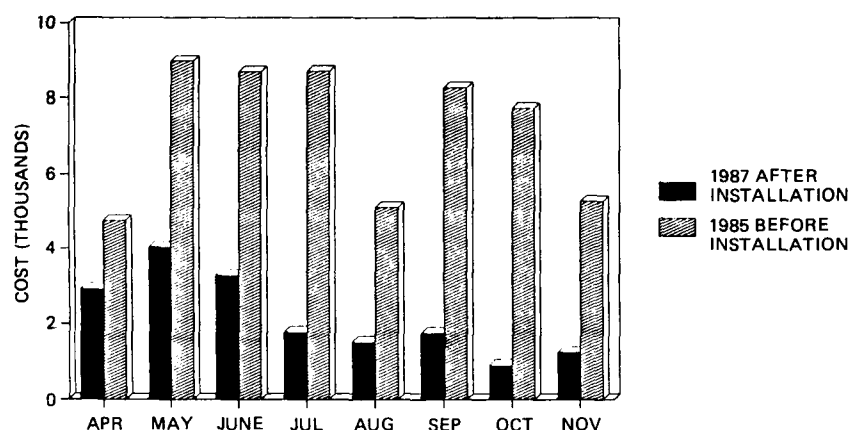
to increase the latent heat-removal capacity. This design feature is particularly attractive for subtropical climates where humidity control is essential to both industrial processes and human comfort.

The unique aspect of the use of heat pipes is that it allows efficient removal of sensible heat from the air approaching the evaporator and transfers it to the air that has passed through the evaporator, providing reheat. In essence, the heat pipes reduce the sensible load on the evaporator, drop the off-coil temperature, and significantly increase moisture removal. The goal of the project is to demonstrate a latent heat fraction of approximately 60 percent, as opposed to 20 to 30 percent typical of conventional units.

The principal contractor is the Florida Solar Energy Center, which recently installed a heat pipe in a warehouse for Bobs Candies in Albany, Georgia as a demonstration project. The project which is in co-operation with Georgia Power has shown a 30 to 50% savings of electrical power. In other terms, the cost of the project was recovered within the first year of operation.

James K. O'Malley, 867-3688

DF-FED-32



*Comparative Warehouse Electrical Cost Before and After Heat Pipe Installation*

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## PROJECT REFERENCE DATA

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Hydrogen Laser Monitoring System (HLMS)	W.R. Helms 867-4438 DL-ESS-31	Spectral Sciences, Inc. (Dr. S. Adler-Golden)
Rocket Engine Leak Detector Mass Spectrometer (RELDMS)	J.D. Collins, W.R. Helms 867-4438 DL-ESS-31	Perkin-Elmer Corp. (A. Kaplan)
Trace Gas Analyzer (TGA)	J.D. Collins, W.R. Helms 867-4438 DL-ESS-31	Perkin-Elmer Corp. (A. Kaplan)
Backup Hazardous Gas Detection System for Launch of Space Shuttle and Other Hydrogen/Oxygen Propellant Systems	J.D. Collins, W.R. Helms 867-4438 DL-ESS-31	Perkin-Elmer Corp. (R.B. Lehotsky)
Advanced Hazardous Gas Detection System	M. Nurge, J.D. Collins, W.R. Helms 867-4438 DL-ESS-31	Naval Research Laboratory (Dr. J. Wyatt)
An Evaluation of a Turbomolecular-Pumped Quadrupole Mass Spectrometer for Hydrogen Leak Detection	M. Nurge, J.D. Collins, W.R. Helms 867-4438 DL-ESS-31	Monmouth College, N.J. (Dr. D. Waik)
Quantitative Hydrazine Dosimetry	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Naval Research Laboratory (S. Rose-Pehrsson) (J. Wyatt) Geo-Centers, Inc. (P. Taffe)
Colorimetric Hypergolic Fuel Dosimeter Badge	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	GMD, Inc. (Dr. G. Moore)
Photoionization Hypergolic Fuel Vapor Detector	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Naval Research Laboratory (Dr. J. Wyatt) (S. Rose-Pehrsson)
Solid-State Electrochemical Sensors for Hydrazines	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Transducer Research, Inc. (Dr. J. Stetter)



ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Comparative Evaluation of Toxic Vapor Sensors	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Naval Research Laboratory (S. Rose-Pehrsson) (J. Wyatt)
Chemiluminescent Hypergolic Propellant Vapor Detector	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Aerospace Corp. (H. Takimoyo) USAF/Space Division (Capt. J. Betshart) Thermedics, Inc. (F. Fraim)
Evaluation of Sample Line Tubing For MMH Transport	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Naval Research Laboratory (S. Rose-Pehrsson) (P. Taffe)
Toxic and Flammable Gas Detectors	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	NASA White Sands Test Facility (S. Koontz)
Multispectral Imaging of Hydrogen Fires	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	Planning Research Corp. (Dr. S. Gleman)
Solid Rocket Booster Inadvertent Ignition Detection System	J.D. Collins, J.E. Baker, W.R. Helms 867-4438 DL-ESS-31	Planning Research Corp. (Dr. S. Gleman)
Remote Detection and Characterization of Fugitive Hydrogen by Raman LIDAR	M. Nurge, C. Griffin, W.R. Helms 867-4438 DL-ESS-31	Computer Genetics Corp. (B. Caputo)
Remote Sensing of Hydrazine	M.M. Scott, Jr. 867-3475 DL-ESS-32 W.R. Helms 867-4438 DL-ESS-31	Jet Propulsion Laboratory
Minimizing Variability for Optical Particle Counters	J.C. Travis, W.R. Helms 867-4438 DL-ESS-31	University of Arkansas at Little Rock NASA/ASEE Summer Fellow (Dr. A.J. Adams)

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Bolt Gage Development	J.D. Collins, C. Griffin, W.R. Helms 867-4438 DL-ESS-31	Planning Research Corp. (Dr. S. Gleman)
Metals Ignition in High Pressure Oxygen	C.J. Bryan 867-4344 DM-MSL-2	Johnson Space Center White Sands Test Facility
Permeability of Polymers to Organic Liquid and Condensable Gases	C.J. Bryan 867-4344 DM-MSL-2	Tuskegee Institute
Conductive Organic Polymers as Corrosion Control Coatings	C.J. Bryan 867-4344 DM-MSL-2	University of Pennsylvania Los Alamos National Laboratory
Numerical Weather Modeling	R. Wesenberg 867-4438 DL-ESS-31	R*SCAN Corporation Aster Corporation MESO, Inc.
Clear Air-Wind Sensing Doppler Radar (CADR)	R. Wesenberg 867-4438 DL-ESS-31	University of Wisconsin, Stout Air Force Geophysical Laboratory
Thunderstorm Currents	R. Wesenberg 867-4438 DL-ESS-31	University of Arizona Institute of Atmospheric Physics
Expert Mission Planning and Replanning Scheduling System	R. Pierce 867-3526 CS-ISO	The MITRE Corporation
Thunderstorm Weather Forecasting Expert System	A.E. Beller, P. McVeagh 867-3224 DL-ESS-31	Arthur D. Little, Inc.
Effects of Hydration on Cardiovascular System Responses	G.W. Hoffer 867-2964 MD-RES V.A. Convertino 867-4237 MD-RES	The Bionetics Corporation (Dr. M.A. Frey)

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Human Physiological Adaptations to Weightlessness Research Projects	Dr. P. Buchanan 867-2585 MD Dr. V.A. Convertino 867-4237 MD-RES D.F. Doerr, M.R. Duvoisin, A.B. Maples 867-3152 MD-ENG	The Bionetics Corporation (Dr. G.A. Dudley) (K.L. Mathes)
EPCOT Project	W. Knott 853-5142 MD-RES	Walt Disney World
Long-Term Environmental Monitoring Program	W. Knott 853-5142 MD-RES	The Bionetics Corporation (Carlton Hall)
Biomass Conversion	W. Knott 853-5142 MD-RES	The Bionetics Corporation (J. Garland)
Survey of Exercise Equipment for Possible Application to Space Station	Dr. V.A. Convertino 867-4237 MD-RES	The Bionetics Corporation (M.A. Frey) (B. Schonfeld)
Tubular Membrane Plant Growth System	W. Knott 853-5142 MD-RES	The Bionetics Corporation (T. Dreschel)
Controlled Animal Nutrients Delivery System (CANDS)	W. Knott 853-5142 MD-RES	The Bionetics Corporation (M. Lang)
Aquaculture	W. Knott 853-5142 MD-RES	The Bionetics Corporation (P. Mion)
Feasibility Analysis of a High-Efficiency Dehumidifier Air-Conditioner Using Heat Pipes	J.K. O'Malley 867-3688 DF-FED-32	Florida Solar Energy Center

# STANDARD TITLE PAGE

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15. Abstract  As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to future programs. The Engineering Development Directorate encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation, and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1987 Annual Report.  For further technical information about the projects, contact David A. Springer, Projects Management Office, DE-PMO, (305) 867-3035. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.					
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